WEAPON LOCATION-ALLOCATION MODELS FOR DEFENCE PLANNING

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CERTIFICATE

This is to certify that this thesis entitled "Weapon Location Allocation Models for Defence Planning" has been carried out under our supervision by Sqn. Ldr. G.K. Johari, and that it has not been submitted elsewhere for a degree

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ABSTRACT

In this thesis we will develop models for location-allocation of weapons for defence planning.

One of the major problem involved in such modelling is the generation of information needed. We will develop a functional relationship using multiple linear regression between the overall threat at a site (which make it vulnerable to the enemy attack) and the factors like military tactical targets, military strategic targets, economic targets, industrial targets, civil communication and transportation targets, distance from border and military strength of the enemy. Delphi technique is used to generate information needed for the regression model.

Simple location-allocation model for the weapon systems are developed and tested on hypothetical case example.

CHAPTER 1

INTRODUCTION

Unlike the olden days when wars were fought between groups of soldiers only from dawn to dusk, the present day wars involve people from various walks of life in general and scientists and technologists in particular. Gone are the days when people could think that the biologists, the mathematicians, physicists and the other technical people have no role to play in the wars.

With the development of technology and the advent of sophisticated weapon system the problem which are found in logistics of and planning for wars have become very complex.

It was during world war II that the complexity of some of the military situations led to the systematic development of mathematical models to identify solutions. This led to the emergence of operations research. With the development of faster and larger computers it was observed that complex military situations can be modeled and solved effectively using some of these techniques.

Large number of studies dealing with military logistics planning have been reported in the literature since world war II. Possibly a still larger number of studies could not be published due to secrecy requirements. Further, considerable attention has been paid in the area of war-gaming and combat simulation. Computerised war games and simulation have become effective tools in analysing complex war situations and training military officers

to respond to these situations. Some of the work in this area is discussed in military applications of modeling by Francis P. Hoeber[5].

Allocation and location of weapon system for the defence is another area where systematic mathematical modeling can lead to improved result. Although considerable work has been done in this area, there are very few published reports and hardly any work dealing with the Indian ~~[illegible]~~ situation.

In this thesis we shall attempt to develop models dealing with the location-allocation of the weapon systems for the defence of a hypothesised country.

These studies have an advantage that the action suggested are unbiased but at the same time have a limitation, namely, their utility depends largely on the data fed. Thus, these alternatives can be put down in a presentable and simple form to the commander so as to help him in making a quick decision in different situations.

1.1. Problem Formulation:

Essentially the defence plan for a country means accomplishing the following goals:

(1) To defend it against external threat

(2) To create a feeling of security in the minds of the people of that country.

Thus the aims mentioned above clearly indicate that the problem of the defence of a country which incorporates factors like fear of war, internal disturbances etc., is very complex and intricate. The complexity is further increased due to uncertainties and surprises which are integral part of a war on

one side and subjectiveness and ill-defined structure of internal disturbances on the other. Lack of information, data and published work in this area cause serious difficulties in the formulation of this problem and in the development of appropriate models.

As discussed in the previous section techniques like gaming and simulation models can be used to study the situations which may arise in the military operations.

Sqn. Ldr. K.K. Rao[15] in his work on "Air Defence System", stressed on priorities of employing defence weapons against enemy's counter air operation. Capt. D.C.R. Mamtani[2], in his work on "Immediate Air-Support Operation" used the game theoretic approach, for alloting priorities of hit on the basis of pay off function, after assessing one's own and enemy's army strength. Flt. Lt. D.P. Jual[4] in his work on "Close Air Support Operations" has discussed the role of an Air Force commander in decision making for close air support operational by taking into account the bases, aircrafts, weapon system, pilots, weather etc. Sqn. Ldr. S.C. Jain[16] in his work on "Ground Support Air Operation" has considered the joint working of air and ground forces. Abu. S.M. Masud and Peter C. Byrne[1] in their work have developed a linear programming model to determine the optimal allocation of different generic weapon systems to different defensive sectors.

In this thesis we will essentially deal with the problem of locating and allocating weapon systems to meet the defence requirements assessed for the various locations which are vulnerable to the enermy attack.

To achieve this it will become necessary

(1) to develop a methodology for the generation of data or information which is required for the formulation of the problem and the developments of the model,

(2) to construct location-allocation models for the weapon system to account for the various requirements and priorities of the defence plans,

(3) to compare the various models for their performance and implementation using a digital computer,

(4) to judge the robustness of the model by varying the parameters.

1.2. Overall View:

In Chapter 2 of this thesis we will deal with the development of the methodology for data generation for various elements of this problem. In Chapter 3 of this thesis we will discuss the development of mathematical models and simulation on a computer. We will illustrate these models with hypothetical case examples. In Chapter 4 we will summarise the results and discuss the problem extensions.

CHAPTER 2

DATA GENERATION

In the previous chapter we have briefly mentioned the problem which we are going to discuss in this thesis. One of the major requirements in any modeling is the availability of the information needed for the modeling. Assessment of threat and other information required for defence planning to a certain extent, is a subjective.assessment. There are large number of factors, external and internal which contribute to such an assessment.

In this section an attempt will be made to develop a methodology to reach such an assessment in a more objective fashion.

As our goal is to perceive the threat to different locations and to identify the weapon allocation to meet such a threat the assessment will be carried out in the following phases.

Phase 1: Assessment of location based on internal factors hereafter referred to as 'Internal Importance'.

Phase 2: Assessment of a location based on external factors hereafter referred to as 'External Importance'.

Phase 3: Assessment of overall threat.

Phase 4: Assessment of weapon requirement to meet the threat.

2.1. Assessment of Internal Importance:

Importance of a place in any country depends on a number of internal and external factors. In this section a methodology

will be developed to assess the internal importance of a place in two steps.

Step 1: To identify the internal importance and the various factors which contribute towards the internal importance of a place by using Delphi technique.[3]

Step 2: To develop a relationship of the type,

$$I = f(x_1, x_2 \dots x_n)$$

and their coefficients by using multiple linear regression.

2.1.1. Delphi Technique:

In 1966 Olaf Helmer and others at Rand Corporation in U.S.A. developed the Delphi technique which utilizes the positive aspects of 'Panel Technique' and minimises its defects. The Delphi technique can be used to seek a specific forecast of an event, likely to occur in future, or to seek consensus opinions on issues both past and present.

This consensus intuitive technological forecasting technique commences with the identification of a panel of experts. The anonymity of the experts and secrecy of the opinions expressed by them rules out the possibility of influencing others through coercion and eloquence. A questionnaire is given to each panelist, the responses are analysed and a controlled feed back through a subsequent questionnaire is provided. As no opinion is publicly expressed the panelists find it easier to change their opinion if they so desire. The process of getting responses and providing controlled feed backs continues for several iterations after which a consensus opinion emerges.

The Delphi method, unlike other forecasting methods, does not have to furnish a single answer as its output. Instead of reaching a consensus, the Delphi approach can have a spread of opinions, since there is no attempt to get unanimity. The objective is to narrow down the spread of opinions as much as possible without putting any pressure on the respondents. Thus, justified deviant opinion is allowed by the approach. Helmer describes the characteristics of the Delphi technique[3] as follows:

"The effect of placing the onus of justifying relatively extreme responses on the respondents had the effect of causing those without strong convictions to move their estimates closer to the median, while those who felt that they had a good argument for a deviant opinion tended to retain their original opinion and defended it".

The Delphi method is by no means free from disadvantages. The general drawbacks of the techniques given in Wheelwright Sleven C and S. Makridakis[18] are:

(1) Panel members dislike beginning with a blank piece of paper.

(2) The extensive number of interactions required results in a heavy investment of time. The panelist is prone to resent this imposition.

(3) After several rounds, the panelist may be faced with a situation of giving opinions on areas outside his field of expertise.

(4) There is a lack of goal orientation: when does the information become refined enough? when do we stop the iteration process?

(5). The basic design of this technique precludes the give and take, potentially possible in face to face confrontation.

(6) The problem of finding experts to form the panel can be a tricky affair.

The complaints against Delphi are relative and the Delphi method has been chosen for this problem out of the available alternatives.

2.1.2. Case Example:

A case example has been worked out in this section to illustrate the methodology by selecting any 20 sites in the country. In the real-life situation all the sites will have to be considered in a similar manner.

2.1.2.1. Constitution of Delphi Panel:

The panel consisted of ten panelists from the following fields:

(1) Serving and retired officers of the Army, the Navy and the Air Force.

(2) Professors and students of I.I.T. Kanpur who have interest in this field.

(3) Scientists from Defence laboratories.

2.1.2.2. Iteration I:

All the panelists were given a list of 20 places and were asked to do the following:

(1) to allot an absolute importance index to each place within the scale of 1 to 20; 1 indicating the least important place and 20 indicating the critically important or most important

place, considering only the internal factors like military establishments and installations, economic factors, industrial factors, political factors etc.

(2) to give a list of factors which should be considered while assessing the internal importance of any place.

All the answers were scrutinized and a comprehensive list of all the factors was made as under:

(1) Industrial centres

(2) Trade centres

(3) Harbour facilities

(4) Capital/metropolitan cities

(5) Public morale - places of historic, religious and sentimental importance

(6) Strategic locations

(7) Defence production centres

(8) Defence installations

(9) Natural resources

(10) Rail/road heads

(11) Economic factors

(12) Political consideration

(13) Geographical consideration

(14) Food belt/industry

(15) Population density.

It was also observed that the importance index varied quite widely, mainly because some panelists did not possess sufficient information about places in terms of installations, resources, industries, military concentrations, geographical locations etc.

2.1.2.3. Iteration II:

All the panelists were given the detailed information about military installations, major industries/around, natural resources etc. with respect to each one of the 20 places and were asked to revise their assessment if they so desired in view of the additional information given to them.

All the factors listed by the panelists were grouped in 5 major heads and other factors were put as sub-heads. The panelists were asked whether the arrangement of major heads was suitable and if they disagreed, to indicate

(1) What should be the major heads and

(2) What should be the sub-heads under each major head.

Suggested major heads and sub-heads were as follows:

(1) Tactical Military Targets: Defence installations like airfields, high density military installations, communication centres; dams, bridges, road links for military purpose, geographical considerations.

(2) Strategic Military Targets: Harbour facilities, strategic locations, defence production centres, big power stations.

(3) Economic Targets: Industrial centres, trade centres, natural resources, economic factors, food belt etc.

(4) Political Targets: Capital/metropolitan cities, public morale, places of historic, religious and sentimental importance, political considerations, population density etc.

(5) Civil Transportation and Communication: Rail/road head; communication centres etc.

All the answers were scrutinized and it was observed that all the panelists were of the opinion that the major heads and sub-heads for all the factors were in order and it did not require any change. Importance index for all the places did not vary much and it was possible to find a median with the deviation of ± 2 for most of the places. In some cases there were out-liers and their opinions were disregarded.

2.1.2.4. Iteration III:

All the panelists were given exhaustive information for all the 20 places regarding all the major heads and were asked the following:

(1) to grade all the cities for each single major head within a scale of 1 to 20 giving 1 to minimum importance and 20 to maximum importance

(2) to ask for any specific information in case the information given for any place is not sufficient.

All the answers were scrutinized and it was observed that a consensus was achieved for factors like economic and civil communication and transportation while, for the other three factors no consensus was reached. Panelists rating very high and very low were asked to give their views and their views were circulated among the other panelists so that a suitable (median $\pm$ 2) consensus could be obtained. Result for these iterations are given in Appendices from A to G.

2.1.3. Functional Relationship:

In this section we will establish function relationship between overall importance and the factors contributing to it, During war time it is not possible to form the panel and assess the importance of places. Moreover, it is much easier to find out the importance of a place knowing the relationship and the values of various internal factors, which are easier to assess, than the overall importance of a place.

Keeping in view that such relationships are empirical in nature and are dependent on large number of factors which may not have been considered, we will use statistical techniques, such as multiple linear regression for establishing this relationship.

Multiple regression and correlation analysis is a three step process. In this process, we must:

(1) Describe the multiple regression equation

(2) Examine the multiple regression standard error of estimate and

(3) Use multiple correlation analysis to determine how well the regression equation describes the observed data.

In the present work following relationships have been hypothesised

(1) $$I = \sum_{i=1}^{K} \alpha_i x_i + \underset{K \leqslant j \leqslant 5}{\mathrm{Max}} (x_j)$$

(2) $$I = \alpha_o + \sum_{i=1}^{5} \alpha_i x_i$$

(3) $$I = \sum_{i=1}^{5} (x_i)^{\alpha_i}$$

where x_i = independent variables (individual factors contributing to internal importance)

α_i = weightages for independent variables

α_o = constant.

A standard SPSS package programme for multiple linear regression was run for following cases:

(1) $$I = \alpha_0 + \sum_{i=1}^{5} \alpha_i x_i$$

(2) $$I = \prod_{i=1}^{5} \alpha_0 (x_i)^{\alpha_i}$$

(3) $$I = \alpha_0 + \alpha_1 x_1 x_2 + \alpha_2 (x_3 + x_4 + x_5)$$

(4) $$I = \alpha_0 + \alpha_1 x_1 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5$$

(5) $$I = \alpha_0 + \alpha_1 \text{ Max } (x_1, x_2, x_3, x_4, x_5)$$

(6) $$I = \alpha_0 + \alpha_1 \text{ Max } (x_1, x_2) + \alpha_4 x_4$$

(7) $$I = \alpha_0 + \alpha_1 \text{ Max } (x_1, x_2) + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5$$

(8) $$I = \alpha_0 x_1^{\alpha_1} \; x_2^{\alpha_2} \; x_4^{\alpha_4}$$

where, x_1 = tactical military targets

x_2 = strategic military targets

x_3 = economic targets

x_4 = political targets

x_5 = civil transportation and communication.

The results obtained for these cases are put in Appendix H. A study of these results reveals some very interesting facts like:

(1) In the eight models discussed above, factors like economic importance and civil transportation and communication are not appearing at significant levels. In some models they are appearing at negative levels.

(2) Value of the regression coefficient is high for $(x_i)^{\alpha_i}$ type of model as compared to any other model considered above.

Keeping in view these observations we suggest that the following relationship may explain the dependence of internal importance on various factors

$$I = 0.028 \; x_1^{0.333} \; x_2^{0.376} \; x_4^{0.273}$$

where, I = internal importance of a site

x_1 = importance of a site due to tactical military targets

x_2 = importance of a site due to strategic military targets

x_4 = importance of site due to political targets.

It may be kept in mind that the relationship is empirical and exact value of the coefficients is subject to statistical error. But in any case it definitely provides us evidence of the relative importance of the various factors and their underlying relationship.

2.2. External Importance:

The factors which govern the external importance of any place are:

(1) Distance from the border

(2) Military strength of the attacking country

(3) Probability of attack from the neighbouring countries based on political relations, previous history etc.

To develop a methodology for the generation of external importance of a place, once again Delphi technique has been used. A panel was formed to assess the external importance of a place and the following questions were put to them.

Question 1: Indicate your choice of distances in steps for working out the external importance of the places, so that the effectiveness of attack in anyone step remains the same throughout and is different for other steps.

Question 2: Grade the importance of a place as a function of distance and military strength in a scale of 0 to 20. Zero indicating the minimum threat or zero threat and 20 indicating the maximum threat.

Question 3: Give a suitable classification of neighbouring countries in terms of military strength.

Opinions of all the panelists were obtained and they were circulated among the panelists till a suitable consensus was obtained. Results of the final consensus were as follows:

(1) Distances may be considered in the following steps:

(i) 0-20 kms

(ii) 20-50 kms

(iii) 50-100 kms

(iv) 100-300 kms

(v) 300 kms and above.

(2) Considering the three arms (the Army, the Navy and the Air Force) of military as high, medium and low, countries may be classified in one of the following six classes out of a possible 27 classes:

(i) Low Army; Low Navy; Low Air Force

(ii) Medium Army; Low Navy; Medium Air Force

(iii) Medium Army; Medium Navy; Medium Air Force

(iv) High Army; Medium Navy; Medium Air Force

(v) High Army; Medium Navy; High Air Force

(vi) High Army; High Navy; High Air Force.

(3) Grading of places for external importance may be done with the help of the following Table 2.1 in the scale of 0 to 20. Knowing the military strength of the attacking country. Table 2.1 will give the external importance of any place.

2.3. Overall Threat:

In Section 2.1 and Section 2.2 a methodology has been developed to calculate the internal importance and external importance of a place. With this data in this section a methodology is developed to find the overall threat at any site. The following alternative models are possible:

Table 2.1

Assessment of External Importance

Distances \ Military Strength	Low Low Low	Med Low Med	Med Med Med	High Med Med	High Med High	High High High
0-20 kms	16	19	20	20	20	20
20-50 kms	11	16	17	18	19	20
50-100 kms	5	14	14	16	17	20
100-300 kms	1	9	9	11	15	15
300 and above kms	0	4	4	6	11	13

(1) Overall threat = w_1 (internal importance) + w_2 (external importance)

where w_1 and w_2 are weightages assigned to internal importance and external importance respectively.

(2) Overall threat = Max (internal importance, external importance)

(3) Overall threat = K(Internal importance x External importance

These relationship can be established by a similar procedure discussed in Section 2.1.3. Relationship 3 seems most promising. We hypothesise and use this relationship because it will give very high value to a place where both external and internal importances are high and a very low value to a place where both are low. For all other places the values will be scaled in a manner so that the places get proper representation.

2.4. Threat Vector:

Complete defence plan of the country will depend only on threat vector and a change in this vector will result in complete change of weapon allocation in defence locations. Thus this is the nerve centre of the problem and the number of possibilities to define this vector should be considered very carefully so that the final plan becomes realistic. The following models are suggested for the threat vector:

(1) Taking all the enemies into account at a time i.e. simultaneous attack from all the enemies.

(2) Taking a sub-set E_s of E into account at a time i.e. it is almost impossible that all the neighbours will join together and attack a particular country while a more realistic situation could be a few of the neighbouring countries join together and launch an attack.

(3) Taking the most potent enemy for each place, i.e., one place is being attacked only by one enemy but the enemy may be different for different places.

(4) Taking the most probable enemy into account, i.e., considering the political relations and history of wars fought with each country, one may first decide the most probable enemy and then build the threat vector with respect to this particular enemy.

It is obvious that the number of arms required to defend the country will be the maximum for the first model and the minimum for the fourth model and the arms requirement is in decreasing order. An overall defence policy will select as an

objective, defence against any of the four contingencies mentioned above and accordingly a threat vector can be selected. For the exact calculation of a threat vector the following procedure is suggested.

(1) Form a distance matrix for each neighbouring country and all the sites to be defended.

(2) With the help of the Table 2.1 convert this distance matrix into the external threat matrix for all the places to be defended with respect to each neighbouring country. Thus we know the external threat at all the sites due to various neighbouring countries.

(3) Having known the internal importance for all the sites we can work-out the overall threat to all the sites with respect to various countries using the model developed in Section 2.3.

(4) With the help of the information available in (3) above we can find the desired threat vector as follows:

(i) For model (1), i.e., a simultaneous attack from all the enemies, we take the overall threat vector for all the sites and sum it for all the enemies. This will give the threat vector for this model,

$$T_i = \sum_{j \in E} t_{i,j} \qquad \forall \; i = 1,\ldots,m$$
$$\forall \; j \in E \{1,\ldots,k\}$$

where t_{ij} is the threat at the site with respect to j^{th} enemy

T_i is the total threat at the i^{th} site.

(ii) For model (2), i.e., a simultaneous attack from the current potential enemies $E_s^* \in E$, we take the overall threat vector for all the sites and sum it for all the countries contained in E_s. This will give the threat vector for this model, i.e.

$$T_i = \sum_{j \in E_s} t_{i,j} \qquad \forall \quad i = 1,\ldots,m$$
$$\forall \quad j \in E_s$$

(iii) For model (3), i.e., the most potent enemy for each site we find out the maximum overall threat due to any country to that site and this givesthe threat vector for this model

$$T_i = \max_{j \in E} t_{ij}$$

(iv) For model (4), i.e., the most probable enemy, we take the overall threat vector for that particular country and that will give the threat vector for this model.

2.5. Weapon Requirement:

In this section we will discuss and establish relationship between threat at any site and weapon requirement to defend it successfully.

This problem is quite complex in nature due to the fact that no two places are similar in all respects and their requirement of weapons for defence, will be different. This information is very important because it provides a quantitative picture about the requirement of weapon for a particular place. A knowledge of the requirement of all the places gives the

requirement for the whole country. To develop this information following methodology is suggested:

(1) All the places to be defended are classified into five classes as follows:

(i)	Class I	-	Having threat between 17 to 20
(ii)	Class II	-	Having threat between 13 to 16
(iii)	Class III	-	Having threat between 9 to 12
(iv)	Class IV	-	Having threat between 5 to 8
(v)	Class V	-	Having threat between 0 to 4

This classification has been done for the sake of simplicity. Depending on the complexity of the weapon system and the accuracy desired this classification may be changed to have more or less classes.

(2) A list of weapons available in the country for the purpose of defence may be classified in two ways:

(1) <u>Service wise</u>:

(a) Army weapons: weapons used by army for defence

(b) Navy weapons: weapons used by navy for defence

(c) Air Force weapon: weapons used by Air Force for defence.

(2) <u>Role wise</u>:

(a) Defensive weapon: Weapons used in defensive role e.g. surface to air guided missiles, anti-aircraft guns etc.

(b) Offensive weapon: Weapons used in offensive role e.g. bomber aircraft, sub-marine etc.

(c) Defensive as well as offensive weapon: Weapons used

for defensive role as well as offensive role e.g. fighter aircraft, tanks etc.

(3) A weightage is assigned to each weapon with respect to other weapons if the weapon can be replaced or substituted by some other weapon. If a weapon cannot be substituted by another weapon then the problem may be viewed as k independent problems (k = number of weapons used for defence) and one weapon may be considered at a time.

(4) A minimum number is assigned for each weapon type to defend a class of place as shown in Table 2.2.

Table 2.2

Assessment of Weapon Requirement

Sl. No.	Weapon Type	Minimum Requirement of Weapon for				
		Class I	Class II	Class III	Class IV	Class V
1	Type I	24	12	0	0	0
2	Type II	2	1	0	0	0
3	Type III	3	3	2	1	1
4	Type IV	3	3	3	2	1
5	Type V	10	5	2	0	0
6	Type VI	8	6	4	2	0

(5) An effectiveness table is worked out for each weapon as a function of distance. Opening a defence centre at any place incurs some fixed cost and a running cost to maintain

that base. As such it will not be an optimum solution to open a base at each place for its defence. It may become desirable to defend more number of places from one defence location even at the cost of effectiveness. Table 2.3 gives the effectiveness of a weapon as a function of distance.

Table 2.3

Effectiveness of the Weapon

Sl. No.	Weapon Type	Effectiveness of Weapon in a Area of				
		0-20 km	20-50 km	50-100 km	100-300 km	300 and above
1	Type I	1.0	0.9	0.7	0.3	0.0
2	Type II	1.0	0.5	0.0	0.0	0.0
3	Type III	1.0	0.8	0.5	0.0	0.0
4	Type IV	1.0	0.0	0.0	0.0	0.0
5	Type V	1.0	1.0	1.0	1.0	1.0
6	Type VI	1.0	1.0	1.0	0.4	0.0

Information for Tables 2.2 and 2.3 were developed using the Delphi technique. A panel of serving defence officers was formed and panelists were asked to reply the following questions.

<u>Question 1</u>: What should be the minimum requirement of weapon type 1 to 6 for the effective defence of Class I, Class II, Class III, Class IV, Class V and Class VI places?

Question 2: What will be the effectiveness of a weapon if used for the defence of a place located within a range of 0 to 20 km, 20 to 50 km, 50 to 100 km, 100 to 300 km and more than 300 km away from the location of the defence centre? Indicate this opinion for all the weapons 1 to 6.

Opinion expressed by various panelists to Question 1 and Question 2 are given as Table 2.2 and Table 2.3, respectively.

For a real time model also the same technique can be used by forming a panel of experienced defence officers who have good knowledge of places to be defended, defence centers and weapon characteristics and limitations.

CHAPTER 3

MODEL SIMULATION

In the previous chapter, a methodology has been developed to construct the threat vector, minimum requirement of various weapons to defend a class of site and the effectiveness of various weapons at different distances from the defence centre.

In this chapter we will develop models for allocation of weapons to the different defence centers.

As discussed in Chapter 2 we will assume that one weapon cannot be substituted by any other weapon. In the following sections we will discuss allocation-location models for the weapon distribution.

3.1. Single Attack: No Weapon Limitation:

In the development of this model following assumptions are made:

(1) There are sufficient number of weapons available for allotment to all the defence centres.

(2) More than one site can be defended from one defence centre.

(3) Only one site is attacked at a time in the adjacent sector.

Mathematically this model can be represented as follows:

$$\text{Minimise} \quad \sum_{j=1}^{n} y_j \tag{3.1}$$

Subject to the constraints:

$$\sum_{j=1}^{n} a_{ij} y_j \geq d_i \qquad \text{for } i = 1,2,\ldots,m \tag{3.2}$$

where, d_i is the minimum requirement of weapon to defend the i^{th} site,

a_{ij} is the effectiveness coefficient, i.e., the effectiveness to defend the i^{th} site when the weapon is located at the j^{th} defence centre,

y_j is the number of weapons located at the j^{th} defence centre.

The model discussed above has the following limitations:

(1) It is assumed that an unlimited quantity of each weapon is available.

(2) In case of simultaneous attack the allocation thus made may not be sufficient to defend all the locations simultaneously.

3.2. Single Attack: With Weapon Limitation:

In this model the concept of "Goal Programming" has been incorporated. In case the number of weapons available is less than the minimum number of weapons required by the previous model, then it is obvious that it will not be possible to defend all the sites with 100% effectiveness. Through goal programming, by assigning different weights to the unpreparedness at different sites, it will be possible to model large number of different preferences for the defence.

Mathematically this model can be represented as follows:

$$\text{Minimise:} \quad \sum_{i=1}^{m} w_i \, s_i \tag{3.3}$$

Subject to the constraints:

$$\sum_{j=1}^{n} a_{ij}y_j + S_i \geq d_i \qquad i = 1,\ldots,m \quad j = 1,\ldots,n \tag{3.4}$$

$$\sum_{j=1}^{n} y_j \leq A \tag{3.5}$$

$$0 \leq S_i \leq \alpha_i d_i \qquad i = 1,\ldots,m$$

where, w_i is the weight assigned to unpreparedness at the i^{th} site, $i = 1,\ldots,m$

S_i is the measure of unpreparedness at site i, $i = 1,\ldots,m$

A is the total number of weapons available for allocation to various defence centre

α_i is the degree of unpreparedness allowed at site i;

0 means no unpreparedness is acceptable

1 means complete unpreparedness is acceptable

$0 \leq \alpha_i \leq 1$, $i = 1,\ldots,m$

This model overcomes the limitation of the previous model that the number of weapons are unlimited and thus it is closer to the real life situation. By incorporating the weights in the objective function, this model gives us the flexibility to test the various priorities for defence allocation. Some of such priorities are modeled as follows:

(1) $w_i = 1$ by assuming unit weights to the unpreparedness for each site we are showing our indifference to all the sites or we are assuming that defence of all the sites is equally important. If k is the total requirement of the weapon system to defend all the locations then the objective function value in this case will take the value equal to

$(k - A)$. In fact one need not solve the problem by linear programming, as any feasible allocation of the weapon will be optimal. By assigning $\alpha_i = \frac{k - A}{k}$ for all i we can allocate the weapon system in such a way that all sites are equally unprepared.

(2) $w_i = d_i$ (threat at the site) $i = 1, \ldots, m$, this accounts for the situations varying from the maximum unpreparedness at the least important sites (class V sites) to the minimum unpreparedness at the most important site (class I sites).

(3) $w_j = 2^1 \quad j \in$ Class V sites

$w_j = 2^2 \quad j \in$ Class IV sites

$w_j = 2^3 \quad j \in$ Class III sites

$w_j = 2^4 \quad j \in$ Class II sites

$w_j = 2^5 \quad j \in$ Class I sites

This will put the unpreparedness in an exponential scale for various sites.

(4) $\alpha_i = 0$ for those sites at which unpreparedness is not allowed and $0 \leq \alpha_i \leq 1$ according to the importance assigned to the site.

Thus by manipulating w_i and α_i we can accommodate large number of priorities which may be assigned for weapon allocation.

This model also has the limitation that it considers the attack only at one site in the adjacent sector. Thus, this model may not be directly usable in its present form in the real life situation.

3.3. Simultaneous Attack Model:

Major limitation of the models developed in Sections 3.1 and 3.2 is that they consider attack only at one site. Thus, they become unusable in real life situation. To overcome this limitation and to develop a realistic model, in this section we shall incorporate the concept of simultaneous attack at more tnan one site which will form a sector.

Selection of sites to be attacked at one time is a highly arbitrary thing and it will vary from enemy to enemy, their military preparedness and aims. In our case example we will construct such sectors using some simple rules to be described in Section 3.3.1. Mathematical formulation of the problem incorporating the simultaneous attack is as follows:

Minimise:

$$\sum_{j=1}^{n} c_j x_j + \sum_{i=1}^{m} w_i s_i + \sum_{k=1}^{K} v_k p_k \tag{3.6}$$

Subject to the constraints:

$$\sum_{j=1}^{n} a_{ij}\, y_j^i + s_i \geq d_i \qquad \forall\ i = 1,\ldots,m \tag{3.7}$$

$$\sum_{i \in s_k} \sum_{j=1}^{n} y_j^i + p_k \geq \sum_{i \in s_k} d_i \qquad \forall\ k = 1,\ldots,K \tag{3.8}$$

$$x_j \geq \sum_{i \in s_k} y_j^i \qquad \forall\ \begin{array}{l} j = 1,\ldots,n \\ k = 1,\ldots,K \\ i \in A(j) \end{array} \tag{3.9}$$

$$x_j \geq y_j^i \tag{3.10}$$

$$\sum_{j=1}^{n} x_j \leq A \tag{3.11}$$

$$0 \leq s_i \leq \alpha_i d_i \tag{3.12}$$

A(j) is the set of the sites which can be depended ($a_{ij} > 0$) from defence centre j.

Inequality (3.7) incorporates the relationship between unpreparedness (s_i) on site i with weapon allocated to site i and demand of weapon at site i.

Inequality (3.8) incorporates the relationship between unpreparedness (p_k) in sector k with weapon allocated to all the sites i in sector k and demand of weapon at sector k.

Inequalities (3.9) and (3.10) simply computes a lower bound on the number of weapons (x_j) actually located at defence center j. It may be noted that as the same weapon can be allocated to defend more than one site at a time (not belonging to the same sector), the weapons required to be located at a site are much less than the sum of all the weapons allocated to other sites from this location. The actual number of weapon located at a site is the maximum allocated from that defence centre to all the sites in any sector or any single site. As x_j appears with non-negative coefficient in the objective function (to be minimized) in any optimal solution it will take the value equal to the lower bound.

where:

c_j = weight assigned to defence centres.

x_j = total allocation of weapon at j^{th} defence centre $j = 1,\ldots,n$.

w_i = weight assigned to unpreparedness at i^{th} site.

s_i = unpreparedness at i^{th} site $i = 1,\ldots,m$.

v_k = weight assigned to unpreparedness in k^{th} sector.

p_k = unpreparedness in k^{th} sector, $k = 1,\ldots,K$.

a_{ij} = effectiveness coefficient, i.e., the effectiveness to defend the i^{th} site when the weapon is located at the j^{th} defence centre.

y_j^i = contribution of j^{th} defence centre to defend i^{th} site.

d_i = minimum requirement of weapon to defend the i^{th} site.

A = total number of weapons available for allocation to different defence centres.

α_i = upperbound for site unpreparedness.

In this model, apart from incorporating the concept of simultaneous attack, a set of flexibility has been provided by introducing the terms like $\Sigma\ w_i\ s_i$ and $\Sigma\ v_k\ p_k$ as explained below.

(1) if $w_i = 0$, $v_k = 0\ \forall$ i and k and A = some large number:

Then this model in its simplest form will find out the minimum allotment of weapon at various defence centres to meet the simultaneous threat.

(2) if $c_j = 0$, $v_k = 0\ \forall$ j and k:

This model will minimise the unpreparedness at various sites subject to the weights assigned to various sites,

thus goal programming concept is incorporated.

(3) if c_j and w_i assume some values:

This model will find the optimum assignment of weapon at all the defence centres and minimise the unpreparedness overall the sights. Here also the goal programming concept is incorporated.

(4) Similarly if we assign some weights to v_k then the model will minimize the unpreparedness in all the sectors.

Thus, in this model, the user has got a wide range of parameters to play with and select the most appropriate model suitable to his requirement.

3.3.1. Selection of Sectors:

Selection of s_k (sub-set of sites for attack) is a highly arbitrary and all the possibilities of such selection is beyond the scope of this thesis. However to develop some concepts the following cases have been considered.

(1) Randomly select any proposed n number of places and consider a simultaneous attack at all these places. This will form one such sector. k such random sectors may be selected.

(2) Sectors constituted by any of the following consideration may be considered for the simultaneous attack:

(i) $s_i = \{i \in \text{class I sites}\}$

(ii) $s_i = \{i \in \text{class V sites}\}$

(iii) $s_i = \{i \text{ suchthat } d_i \geq T\}$

In general any other valid consideration which evolves the possibility of simultaneous attack may be used to formulate these sub-sets.

(3) $s_i = \{i \in$ class I sites and all other sites within a specified radious of d kms from $i\}$ $\quad i = 1,\ldots,m$

m = number of class I sites in the country/sector under consideration.

3.4. Fixed Cost Model:

In all the defence models discussed in Sections 3.1 to 3.3, we have considered that any number of defence centres can be opened to meet the threat effectively at various sites. This aspect of the model can be criticised for two reasons mentioned below.

(1) Opening a new base incurs some fixed charges and then it requires running charges to maintain the base.

(2) We have assumed that none of the K weapons can be substituted by anyother weapon. Thus they may be considered as K independent problems. Solution of these K problems may so turn out that they require separate defence centers, which may not be an acceptable situation, because we may not like to open a separate base for one weapon only.

To overcome the limitations mentioned above, in this section we shall develop a model which incorporates cost of the opening the bases. This model may be formulated as follows.

Minimise

$$\sum_{j=1}^{n} c_j z_j + \sum_{k=1}^{K} \sum_{j=1}^{n} y_j^k w_j^k \tag{3.13}$$

subject to the constraints.

$$\sum_{k=1}^{K} y_j^k \leq M z_j \quad \forall \ j = 1,\ldots,n \tag{3.14}$$

$$\sum_{j=1}^{n} a_{ij}^k y_j^k \geq d_i^k \quad \forall \ i = 1,\ldots m \quad k = 1,\ldots k \tag{3.15}$$

$$\sum_{j=1}^{n} z_j \leq N \tag{3.16}$$

$z_j = 1$ if a defence centre is opened at j^{th} location

$= 0$ otherwise.

where:

K = number of types of weapon

c_j = cost of opening j^{th} defence centre

M = some big number ($> \sum_{k=1}^{K} \sum_{i=1}^{m} d_i^k$)

y_j^k = weapon type K allocated to j^{th} defence centre

N = maximum number of defence centres which can be opened

d_i^k = minimum quantity of weapon type k required for i^{th} site.

w_j^k =weightage assigned to j^{th}defence centre for locating k^{th} weapon.

This model can be considered as a very close approximation to the real life situation, c_j and w_j^k weights are introduced in the objective function to keep flexibility in the model. By assigning a very high value to c_j we can ensure that a defence center is not opened at site j. Similarly by assigning a very high weight to w_j we will see that a weapon is not allocated to j^{th} site. It may be used as an indirect method to incorporate a factor like geographical location which has not

been considered in the model formulation. This model can be easily extended to incorporate unpreparedness objective and simultaneous attack requirements. Keeping in view that it is a mixed integer programming model, any addition to the number of variables will usually leadto a higher computational time.

3.5. Analysis of Case Examples and Computer Results:

In order to illustrate the applicability of the models proposed in Section 3.1 to Section 3.4, two sets of data of 20 sites each, one for the overall defence of the country and the other for the sectorial defence of the country are considered. For each set a distance matrix was constructed by measuring the distance between all the sites and then this distance matrix was converted into an effectiveness matrix with the help of Table 2.3 for weapon type I. Distance matrix and the effectiveness matrix thus constructed are put in Appendices from I to L for both the sets of data. Threat vectors, minimum weapon requirements and weights are arbitrarily chosen and has no relevance to any specific situation. All the programmes for solving these models are written in FORTRAN-10 and solved on DEC-1090 (KL-40) time sharing system. In the following section we shall discuss the performance of the models for the case examples.

3.5.1. Single Attack: No Weapon Limitation:

An IMSL programme ZX3LP has been used for solving linear programming problems. The results obtained for this model are put in Tables 3.1 and 3.2, constraints were formulated as given in Section 3.1. Each defence centre in the objective function

Table 3.1

Results of No Weapon Limitation Model - Sectorial Defence

Site numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Minimum requirement	24	12	0	12	24	24	12	24	0	24	0	12	24	0	12	24	24	0	12	12
Allocation of weapon	9	0	0	0	0	0	0	0	0	14	0	0	0	0	0	11	14	0	0	0

Table 3.2

Results of No Weapon Limitation Model - Overall Defence

Site numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Minimum requirement	24	12	0	12	24	24	12	24	0	24	0	12	24	0	12	24	24	0	12	12
Allocation of weapon	24	10	0	12	24	24	12	24	0	24	0	6	24	0	12	24	24	0	11	12

was given equal importance. Total number of weapon required for the sectional defence and overall defence of the country turns out to be 48 and 267 respectively. It may be noted that linear programming may provide fractional weapon allocations. Keeping in view that usually number allocated are reasonably large, without loss of generality we will round them up to get integer value whenever needed.

In this model it can be seen that the allocation of weapon depends more on the effectiveness matrix and it is quite possible that, contrary to expectation, the allocation may be made to sites which in the model have low defence requirement. This is simply due to the reason that these sites are able to defend the other sites effectively.

3.5.2. Single Attack: Limited Weapons:

For the simulation of this model also IMSL programme ZX3LP was used. Model is analysed for following cases:

(1) $w_i = 1$ for $\forall$ $i = 1,2,\ldots m$

(2) $w_i = d_i$ for $\forall$ $i = 1,2,\ldots m$

(3) Exponential weights.

For all the cases we shall assume $\alpha_i = 1$ for all $i = 1,\ldots,m$.

Results for sectorial defence model show that the unpreparedness appears at site number 17 irrespective of the weights assigned to the sites in cases mentioned above. It may be due to the structure of the matrix.

Results for overall defence model show that distribution of the unpreparedness varies by changing the weights assigned to

the sites in the three cases mentioned above. Thus, it can be seen that weightage can make significant changes in the model.

3.5.3. Simultaneous Attack Model:

For the simulation of this model IMSL programme ZX3LP was used. We shall assume the following:

$K = 1$

$w_i = 0$ for $\forall$ $i = 1,\ldots,m$

$v_k = 0$ for $\forall$ $k = 1,\ldots,k$

$\alpha_i = 1$ for $\forall$ $i = 1,\ldots,m$

$A = 1000$ (some big number, more than the total requirement of all the sites).

This case example assumes that all the sites which can be attacked simultaneously form one sector and hence $K = 1$. Total number of weapons required for the sectorial defence model turns out to be 154. Comparing this number with that obtained in Section 3.5.1, shows that there is a sizeable difference in the requirement of weapon for two cases. This indicates that change in objective results in considerable change in requirement of the weapon.

3.5.4. Fixed Cost Model:

In this case example 10 sites and 3 different weapons have been considered. In certain case examples we were considering 20 locations and 6 different weapon systems. Keeping in view that in the mixed-integer programming model which we are going to use computational time increases exponentially

with the number of variables (m + mk). We will solve the smaller example with m = 10, k = 3. Further we will not incorporate simultaneous attack and unpreparedness constraints for the same reason. In actual cases with sufficient computer time it is possible to solve problems upto 200-300 variables.

We will use mixed integer programme developed by A.H. Land and A.G. Doig as given in Optimization Techniques with Fortran by J.L. Kuester and J.H. Mize[8].

This programme was run for 4 different values of N (maximum number of defence centres permitted). The results of these four cases are given in Table 3.3.

Table 3.3

Performance of Fixed Cost Model

Maximum Number of Defence Centres to be Located	Number of Iterations Required	CPU Time	Value of Objective Function
5	1751	27.43	155
6	1345	23.70	186
8	204	5.87	248
10	0	0.69	310

Results clearly indicate that a little change in one constraint introduces a lot of change in the number of iteration and CPU time to solve the problem.

CHAPTER 4

CONCLUSION AND SCOPE FOR FURTHER WORK

In Chapter 2 we have discussed various factors which make a site vulnerable to the enemy attack and have developed a methodology to determine the various elements which are needed to construct the threat vector and minimum requirement of weapon types to defend any site. In Chapter 3 we have developed mathematical models and discussed their relative merits and demerits. Simulation of these models on a digital computer has also been done and the results have been discussed.

Results discussed in Section 3.5 clearly show that:

(1) Some results are contrary to the normal expectation.

(2) A little change in parameters can completely change the allocation of weapons to the defence centres.

(3) A little change in the number of variables and data can result in large change in CPU time of a digital computer to solve the problem.

4.1. Limitations:

In the development of these models while considering the internal importance and external importance of a place and assigning the weapon to a particular defence centre for the defence of a site some factors like geographical location, terrain in that area, etc., have not been incorporated in the model. This may pose a serious problem in real situation for example a place falling under the category of class I site

may have a location near sea-shore or near plain fields or near a mountain valley. The place near the sea-shore will need more of naval weapon to meet the threat from the sea-side rather than army weapons because there cannot be any threat from army side. Similarly a place in the mountain-valley will need more of army weapons than the navy or air force weapons. The reason being it will not face any threat from navy and very little threat from air force.

All the models considered in this work are static. This is another limitation. Because, in the military operations the situations change very fast and if the parameters in the model do not take care of such eventualities the results may become inconsequent and even disastrous.

4.2. Scope for Further Work:

Further work in the following areas is suggested:

(1) More analytical study of factors which contribute towards the importance of a place and the evaluation of the threat vector.

(2) Study of more technological forecasting techniques for generation of more accurate data for the success of the models.

(3) Studies leading to the development of dynamic models which can simulate military operations more closely.

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APPENDIX A

DELPHI TECHNIQUE ITERATION I: OVERALL IMPORTANCE FOR THE SITES

Site No.	Panelist 1	2	3	4	5	6	7	8	9	10	Median	Outliers
1	16*	6*	10	10	7*	8	14*	12	10	12	10	4
2	15	18	18	17	8*	12*	12*	20*	18	16	17	4
3	15*	8	7*	13*	9	12	15*	12	8	10	10	4
4	16	15	17*	6*	4*	6*	14	16	12	14	14	4
5	18	18	16	13*	16	18	18	16	16	14	16	1
6	18	18	17	12*	12*	17	16	16	14	12*	16*	3
7	16*	7*	9	12	12	8	13*	12	14*	8	10	4
8	18	19	17	13*	11*	20	20	16	20	18	18	2
9	15	17	17	7*	9*	12*	12*	16	16	14	15	4
10	14	13	16*	5*	7*	10	11	14	14	16*	12	4
11	14	14	10	11	10	8*	11	18*	14	16*	12	3
12	17	19*	15	13*	11*	14	15	20*	14	18	16	4
13	15	4*	10*	12	8*	6*	13	14	12	18*	13	5
14	16*	4*	9	9	10	6*	12	20*	16*	16*	10	6
15	14*	5*	11	10	9	4*	9	14*	6*	8	9	5
16	12*	6	4	7	4	1*	2*	6	4	6	6	3
17	15*	4*	8*	9	10	10	13	16*	16*	12	11	5
18	15	13	12	9*	12	1*	8*	16	16	12	14	3
19	15	17	15	12*	8*	6*	18	20*	20*	16	17	5
20	16	6*	10*	13	12	10*	14	12	14	14	14	3

Outlayer $\longrightarrow$ $|\text{observed} - \text{median}| \geq 2$

* Indicates outliers.

APPENDIX B

DELPHI TECHNIQUE ITERATION II (FINAL ITERATION): OVERALL IMPORTANCE FOR THE SITES

Site No.	Panelist										Median	Outliers
	1	2	3	4	5	6	7	8	9	10		
1	10	4*	10	12	8	10	14*	10	10	12	10	2
2	17	18*	17	17	10*	13	13	16	15	16	15	2
3	10	11	9	15*	10	12	12	12	15*	10	10	2
4	12	11	12	6*	4*	12	14	15	13	14	13	2
5	20	20	18	13*	17	20	18	20	20	17	19	1
6	20	20	18	12*	12*	20	16	20	20	16	18	2
7	12	14	11	10*	12	13	14	13	15	8*	13	2
8	20	17	17	14*	12*	18	20	18	20	18	18	2
9	12	18*	14	8*	11	14	12	13	10	14	12	2
10	10	10	14*	4*	8	10	11	12	10	12	10	2
11	10	12	10	10	10	12	11	14	10	12	12	0
12	16*	13	15	15	11	14	13	15	10*	15	13	2
13	10	8	10	14*	8	10	12	9	10	15*	10	2
14	18*	10	9	8	10	10	12	11	5*	12	10	2
15	15	16	12	9*	13	16	13	16	20*	12	14	2
16	5	3	4	4	4	5	2	9*	10*	5	3	2
17	10	12	10	8*	10	10	13	12	10	12	12	1
18	15*	12	12	8*	12	12	13	14	10	12	12	2
19	13	15	15	14	8*	13	17	18*	16	16	15	2
20	15	13	11	16*	12	11	14	13	15	14	13	1

Outlayer ⟶ | observed - median | ≥ 2

* Indicates outliers.

APPENDIX C

DELPHI TECHNIQUE ITERATION I (FINAL ITERATION): ASSESSMENT OF CIVIL TRANSPORT & COMMUNICATION TARGETS

Site No.	Panelist 1	2	3	4	5	6	7	8	9	10	Median	Outliers
1	12	10	12	12	16*	12	10	13	14	12	12	1
2	10	10	12*	8	8	7	6	7	10	9	8	1
3	16	12	16	14	12	16	14	15	12	13	14	0
4	18	15	16	14	17	18	15	10*	18	9*	16	2
5	20	12*	16	16	19	20	16	20	20	18	18	1
6	20	18	16	16	19	20	16	20	20	16	18	0
7	12	8	8	8	12	12	9	10	6*	12	10	1
8	20	19	16	16	12*	20	20	19	19	18	18	1
9	12*	17	16	14	18	14	14	15	17	16	16	1
10	9	13	12	5*	10	9	10	10	6*	9	11	2
11	8	12	12	8	15*	11	8	10	10	9	10	1
12	16	17	4*	14	17	17	13	10*	13	14	15	2
13	8	4	4	5	6	12*	6	5	6	8	6	1
14	4	4	6	5	16*	4	2	4	3	4	4	1
15	20*	15	13	14	13	20*	13	14	15	16	15	2
16	10	6	10	6	10	8	6	8	8	6	8	0
17	5	4	1	3	2	4	2	1	2	5	3	0
18	4	3	3	4	4	6	2	3	3	5	4	0
19	12	11	10	8	12	12	2*	10	11	12	10	1
20	12	8	10	10	18*	10	10	11	10	12	10	1

Outlayer $\longrightarrow$ $|\text{observed} - \text{median}| \geq 2$

* Indicates outliers.

APPENDIX D

DELPHI TECHNIQUE ITERATION I (FINAL ITERATION): ASSESSMENT OF ECONOMIC TARGETS

Site No.	Panelist 1	2	3	4	5	6	7	8	9	10	Median	Outliers
1	17	18	8*	15	18	18	14	16	18	15	16	1
2	12	17*	10	8	9	8	10	10	9	10	10	1
3	16	16	16	16	18	18	14	15	17	17	16	0
4	16	16	18	12*	15	16	14	16	16	16	16	1
5	20	19	17	18	20	20	18	20	20	19	19	0
6	20	18	12*	16	19	20	18	20	20	18	18	1
7	14*	8	8	10	12	16	14*	10	11	11	10	2
8	15	15	12	11	12	15	15	15	20*	20*	13	2
9	12	14*	12	12	10	12	10	10	11	10	10	1
10	4	5	12*	4	5	5	4	3	5	6	5	1
11	7	8	8	8	16*	9	9	6	8	6	8	1
12	4	7	4	5	5	8	4	3*	5	8	6	1
13	4	5	6	5	3	9*	7	4	5	7	5	1
14	4	4	7*	1	1	5	2	4	4	5	3	1
15	20	18	12*	16	16	20	16	20	20	18	18	1
16	10	8	10	8	6	6	6	10	10	10	8	0
17	6	4	6	5	2	6	2	5	7*	6	4	1
18	4	4	4	4	2	5	2	4	4	6	4	0
19	4	5	5	5	2	5	2	2	2	5	3	0
20	16*	10	10	12	14	12	14	13	11	12	12	1

Outlayer $\longrightarrow$ $|\text{observed} - \text{median}| \geq 2$

* Indicates outliers.

APPENDIX E

DELPHI TECHNIQUE - ITERATION II (FINAL ITERATION): ASSESSMENT OF MILITARY TACTICAL TARGETS

Site No.	Panelist 1	2	3	4	5	6	7	8	9	10	Median	Outliers
1	4*	10	14	10	6*	12	10	13	11	10	12	2
2	16	20*	16	18	16	7*	16	17	15	16	16	2
3	4*	8	13*	7	8	8	10	6	10	8	8	2
4	4*	10	10	10	8	18*	10	9	9	10	10	2
5	20	18	18	17	20	20	18	19	20	17	18	0
6	20	18	13*	15	18	20	18	17	19	13*	18	2
7	12	10	10	12	10	18*	12	11	15*	12	11	2
8	20	18	16	10*	16	20	20	15*	19	16	18	2
9	16	16	12	12	12	18*	16	14	14	13	14	2
10	8	17*	12	8	12	8	12	10	11	16*	10	2
11	12	10	14	9*	13	11	16*	12	12	10	12	2
12	12*	17	15	12*	18	18	16	17	19	15	17	2
13	12	11	13	13	15	12	12	13	16*	11	13	1
14	16	18	16	14	18	16	17	16	17	15	16	0
15	8	6	6	5	8	20*	9	6	5	8	7	1
16	4	4	1	4	3	8*	1	2	2	11*	3	2
17	8*	10	1*	12	14	14	12	11	13	10	12	2
18	4*	12	1*	12	12	8	10	11	13	9	10	2
19	16	17	14	14	18	12*	17	11*	14	14	16	2
20	20	16	12*	13*	19	18	17	18	18	17	18	2

Outlayer $\longrightarrow$ $|\text{observed} - \text{median}| \geq 2$

* Indicates outliers.

APPENDIX F

DELPHI TECHNIQUE - ITERATION II (FINAL ITERATION): ASSESSMENT OF MILITARY STRATEGIC TARGETS

Site No.	Panelist										Median	Outliers
	1	2	3	4	5	6	7	8	9	10		
1	12	16	9*	15	9*	16	12	13	15	15	14	2
2	16	18	20	12*	19	14*	18	19	17	16	18	2
3	16	12*	16	16	18	18	16	16	16	17	16	1
4	12	17*	18*	12	12	12	15	11	15	13	13	2
5	20	16	18	16	20	20	18	20	19	18	18	0
6	20	20	16	15*	19	20	18	20	20	14*	18	2
7	16	16	14	14	12	12	12	17*	18*	15	14	2
8	20	16	20	12*	15*	20	18	19	19	18	18	2
9	12	13	16*	12	15	18	10*	12	14	15	13	2
10	4	6	5	4	12*	6	8	7	8	11*	6	2
11	12	8*	11	13	13	14	8*	12	12	12	13	2
12	16	17	17	16	17	14	15	13*	12*	15	16	2
13	16*	12	10	11	13	12	9*	14	14	11	12	2
14	8	8	9	13*	12	14*	10	11	12	10	10	2
15	12	16	12	12	12	18*	13	13	15	12	14	1
16	4	4	3	5	5	5	1	3	2	11*	3	1
17	16	13	16	14	19*	16	12	15	16	13	14	1
18	12	8	10	10	14*	12	12	9	13*	10	10	2
19	16	18	15	15	19	16	10*	18	18	15	17	1
20	20*	16	15	15	20*	18	17	17	17	16	17	2

Outlayer ⟶ | observed - median | ≥ 2

* Indicates outliers.

APPENDIX G

DELPHI TECHNIQUE - ITERATION II (FINAL ITERATION): ASSESSMENT OF POLITICAL TARGETS

Site No.	Panelist										Median	Outliers
	1	2	3	4	5	6	7	8	9	10		
1	12	6*	8	12	5*	12	9	11	9	10	10	2
2	13	17	18*	14	15	9*	15	13	14	17	15	2
3	12	8*	4*	12	11	15	11	12	12	14	13	2
4	8	8	16*	8	6	10	4*	7	9	8	8	2
5	19	15	12*	14*	15	19	16	18	18	18	17	2
6	20	17	16	14*	18	20	16	19	19	17	18	1
7	16*	10	8*	12	10	10	11	13	11	15	12	2
8	20	20	18	19	20	20	20	17*	16*	20	20	2
9	12	8	16*	10	12	10	6*	9	9	8	10	2
10	12	10	14	5*	11	20	5*	13	10	8	12	2
11	4	6	15*	6	16*	8	6	7	8	7	6	2
12	12	13	18*	11	14	16*	13	14	15	13	13	2
13	8	6	10	12*	8	10	6	13	7	8	8	2
14	12*	14*	6	4	3	2	2	5	3	6	4	2
15	20*	[illegible]	11	13	11	13	11	12	14	14	13	1
16	12*	6	4	8	5	7	6	5	5	9*	6	2
17	9	8	7	8	10	10	8	7	8	9	9	0
18	12	17*	8	8	12	10	8	11	13*	8	10	2
19	16	17	17	9*	16	20*	16	14	17	15	15	2
20	20*	11	12	10	6*	10	9	10	10	13	11	2

Outlayer ⟶ | observed - media | $\geq$ 2

* Indicates outliers.

APPENDIX H

RESULTS OF LINEAR MULTIPLE REGRESSION CASES

Sl. No.	Regression Equations	α_0	α_1	α_2	α_3	α_4	α_5	Multiple R
1	$y = \alpha_0 + \sum_{i=1}^{5} \alpha_i x_i$	0.679	0.315	0.175	0.091	0.384	-0.005	0.91954
2	$y = \prod_{i=1}^{5} \alpha_0 (x_i)^{\alpha_i}$	0.021	0.338	0.373	0.003	0.267	-0.007	0.93141
3	$y = \alpha_0 + \alpha_1 x_1 x_2 + \alpha_2 (x_3 + x_4 + x_5)$	0.493	0.198	0.123				0.83451
4	$y = \alpha_0 + \alpha_1 x_1 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5$	0.360	0.0186		-0.022	0.414	0.627	0.91283
5	$y = \alpha_0 + \alpha_1 \text{ Max}(x_1, x_2, x_3, x_4, x_5)$	-2.222	0.950					0.80519
6	$y = \alpha_0 + \alpha_1 \text{ Max}(x_1, x_2) + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5$	0.202	0.471		0.015	0.422	0.039	0.90602
7	$y = \alpha_0 + \alpha_1 \text{ Max}(x_1, x_2) + \alpha_4 x_4$	0.138	0.533			0.391		0.89652
8	$y = \alpha_0 x_1^{\alpha_1} x_2^{\alpha_2} x_4^{\alpha_4}$	0.028	0.333	0.376		0.273		0.93135

APPENDIX I

DISTANCE MATREIX FOR SECTORIAL DEFENCE

0.00	0.90	1.10	1.20	0.40	1.40	1.40	0.70	1.80	1.90	2.50	1.00	0.40	1.50	1.20	0.60	2.00	1.50	1.20
0.90	0.00	1.80	1.10	1.30	1.50	2.30	3.50	1.60	1.70	1.00	1.50	5.50	0.60	1.80	1.10	2.40	1.20	2.40
1.10	1.80	0.00	1.50	0.75	1.50	0.40	1.60	1.90	1.90	1.20	1.90	1.40	2.40	3.50	0.85	1.40	1.80	2.10
1.20	1.10	1.50	0.00	1.30	0.40	1.85	0.80	0.60	0.70	1.45	1.20	1.10	1.30	1.30	0.75	1.45	3.50	1.30
0.40	1.30	0.75	1.30	0.00	1.50	1.10	1.00	1.80	2.00	0.45	1.40	0.75	1.90	0.95	0.65	1.80	1.60	1.60
1.40	1.50	1.50	0.40	1.50	0.00	1.80	1.10	0.50	0.50	1.70	1.50	1.40	1.70	1.20	0.90	1.10	0.50	1.60
1.40	2.30	0.40	1.80	1.10	1.80	0.00	2.00	2.20	2.20	1.50	2.40	1.70	2.80	0.55	1.20	1.40	2.10	2.60
0.70	0.35	1.60	0.80	1.00	1.10	2.00	0.00	1.30	1.50	0.90	0.50	0.40	0.80	1.50	0.80	0.21	1.00	0.65
1.80	1.60	1.90	0.60	1.80	0.50	2.20	1.30	0.00	0.20	2.00	1.60	1.70	1.60	1.70	1.20	1.40	0.35	1.60
1.90	1.70	1.90	0.70	2.00	0.50	2.20	1.50	2.00	0.00	2.20	1.80	1.80	1.80	1.70	1.30	1.20	0.55	1.90
2.50	1.00	1.20	1.40	0.45	1.70	1.50	0.90	2.00	2.20	0.00	1.10	0.50	1.60	1.40	0.90	2.20	1.70	1.30
1.00	1.50	1.90	1.20	1.40	1.50	2.40	0.50	1.60	1.80	1.10	0.00	0.70	0.45	2.00	1.20	0.20	1.30	0.20
0.40	0.50	1.40	1.10	0.75	1.40	1.70	0.40	1.70	1.80	0.50	0.70	0.00	1.10	1.50	0.70	2.10	1.30	0.85
1.50	0.60	2.40	1.30	1.90	1.70	2.80	0.80	1.60	1.80	1.60	0.45	1.10	0.00	2.40	1.50	2.80	1.30	0.30
1.20	1.80	3.00	1.30	0.95	1.20	0.50	1.50	1.70	1.70	1.40	2.00	1.50	2.40	0.00	0.80	1.00	1.60	2.20
0.60	1.10	0.80	0.70	0.60	0.90	1.20	0.80	1.20	1.30	0.90	1.20	0.75	1.50	0.80	0.00	1.40	1.00	1.40
2.00	2.40	1.40	1.40	1.80	1.10	1.40	2.10	1.40	1.20	2.20	2.50	2.10	2.80	1.00	1.40	0.00	1.50	2.60
1.50	1.20	1.80	0.35	1.60	0.50	2.10	1.00	0.35	0.55	1.70	1.30	1.30	1.30	1.60	1.00	1.50	0.00	1.30
1.20	0.30	2.10	1.30	1.60	1.60	2.60	6.50	1.60	1.90	1.30	0.20	0.85	0.30	2.20	1.40	2.60	1.30	0.00
1.10	1.50	0.80	0.80	1.00	0.65	1.10	1.20	1.10	1.20	1.30	1.60	1.20	1.90	0.55	0.50	0.90	1.00	1.80

APPENDIX J

DISTANCE MATRIX FOR OVERALL DEFENCE

0.00	9.00	11.00	12.00	4.00	14.00	14.00	7.00	18.00	19.00	2.50	10.00	4.00	15.00	12.00	6.00	20.50	15.00	12.00	11
9.00	0.00	18.50	11.00	13.00	15.00	23.00	3.50	16.00	17.50	10.50	1.50	5.50	6.00	18.50	11.00	24.00	12.50	3.00	15
11.00	18.50	0.00	15.00	7.50	15.00	4.00	16.00	19.00	19.00	12.00	19.50	14.00	24.00	3.50	8.50	14.00	18.00	21.50	8
12.00	11.00	15.00	0.00	13.50	4.00	18.50	8.00	6.00	7.00	14.50	12.00	11.00	13.00	13.50	7.50	14.50	3.50	13.00	8
4.00	13.00	7.50	13.50	0.00	15.00	11.00	10.50	18.50	20.00	4.50	14.00	7.50	19.50	9.50	6.50	18.50	16.50	16.00	10
14.00	15.00	15.00	4.00	15.00	0.00	18.00	11.50	5.00	5.00	17.00	15.50	14.50	17.00	12.00	9.00	11.00	5.00	16.50	6
14.00	23.00	4.00	18.50	11.00	18.00	0.00	20.00	22.50	22.50	15.00	24.00	17.50	28.00	5.50	12.50	14.50	21.50	26.00	11
7.00	3.50	16.00	8.00	10.50	11.50	20.00	0.00	13.50	15.00	9.50	5.00	4.00	8.50	15.50	8.00	21.00	10.00	6.50	12
18.00	16.00	19.00	6.00	18.50	5.00	22.50	13.50	0.00	2.00	20.50	16.00	17.00	16.00	17.00	12.50	14.50	3.50	16.50	11
19.00	17.50	19.00	7.00	20.00	5.00	22.50	15.00	2.00	0.00	22.00	18.00	18.50	18.50	17.00	13.50	12.50	5.50	19.00	12
2.50	10.50	12.00	14.50	14.50	17.00	15.00	9.50	20.50	22.00	0.00	11.50	5.00	16.50	14.00	9.00	22.50	17.50	13.00	13
10.00	1.50	19.50	12.00	14.00	15.50	24.00	5.00	16.00	18.00	11.50	0.00	7.00	4.50	20.50	12.50	25.00	13.00	2.00	16
4.00	5.50	14.00	11.00	7.50	14.50	17.50	4.00	17.00	18.50	5.00	7.00	0.00	11.50	15.00	7.50	21.50	13.50	8.50	12
15.00	6.00	24.00	13.00	19.50	17.00	28.00	8.50	16.00	18.50	16.50	4.50	11.50	0.00	24.00	15.50	28.00	13.00	3.00	19
12.00	18.50	3.50	13.50	9.50	12.00	5.50	15.50	17.00	17.00	14.00	20.50	15.00	24.00	0.00	8.00	10.50	16.50	22.00	5
6.00	11.00	8.50	7.50	6.50	9.00	12.50	8.00	12.50	13.50	9.00	12.50	7.50	15.50	8.00	0.00	14.50	10.50	14.00	5
20.50	24.00	14.00	14.50	18.50	11.00	14.50	21.00	14.50	12.50	22.50	25.00	21.50	28.00	10.50	14.50	0.00	15.50	26.00	9
15.00	12.50	18.00	3.50	16.50	5.00	21.50	10.00	3.50	5.50	17.50	13.00	13.50	13.00	16.50	10.50	15.50	0.00	13.00	10
12.00	3.00	21.50	13.00	16.00	16.50	26.00	6.50	16.50	19.00	13.00	2.00	8.50	3.00	22.00	14.00	26.00	13.00	0.00	18
11.00	15.50	8.00	8.00	10.00	6.50	11.00	12.00	11.00	12.00	13.50	16.50	12.50	19.50	5.50	5.00	9.50	10.50	18.00	0

APPENDIX K

EFFECTIVENESS MATRIX FOR SECTORIAL DEFENCE FOR WEAPON TYPE I

-1.00	-0.70	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-
-0.70	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.30	-0.30	-0.30	-0.30	0.00	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-
-0.30	-0.30	-1.00	-0.30	-0.70	-0.30	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.70	-0.30	-0.30	-0.30	-
-0.30	-0.30	-0.30	-1.00	-0.30	-0.90	-0.30	-0.70	-0.70	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	0.00	-0.30	-
-0.90	-0.30	-0.70	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.70	-0.30	-0.70	-0.70	-0.30	-0.30	-0.30	-
-0.30	-0.30	-0.30	-0.90	-0.30	-1.00	-0.30	-0.30	-0.70	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-
-0.30	-0.30	-0.90	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-
-0.70	-0.90	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.70	-0.70	-0.90	-0.70	-0.30	-0.70	-0.90	-0.30	-0.70	-
-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-1.00	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-
-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-
-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-1.00	-0.30	-0.70	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-
-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.70	-0.90	-0.30	-0.30	-0.90	-0.30	-0.90	-
-0.90	-0.70	-0.30	-0.30	-0.70	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.70	-1.00	-0.30	-0.30	-0.70	-0.30	-0.30	-0.70	-
-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.90	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.90	-
-0.30	-0.30	0.00	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.70	-0.30	-0.30	-0.30	-
-0.70	-0.30	-0.70	-0.70	-0.70	-0.70	-0.30	-0.70	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.70	-1.00	-0.30	-0.30	-0.30	-
-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-
-0.30	-0.30	-0.30	-0.90	-0.30	-0.70	-0.30	-0.30	-0.90	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.30	-
-0.30	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.30	-0.30	-0.30	-0.90	-0.70	-0.90	-0.30	-0.30	-0.30	-0.30	-1.00	-
-0.30	-0.30	-0.70	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.70	-0.70	-0.30	-0.30	-1

APPENDIX D

EFFECTIVENESS MATRIX FOR OVERALL DEFENCE FOR WEAPON TYPE I

-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1

```
C   ***********************************************************************
C          THIS PROGRAM IS FOR NO WEAPON LIMITATION MODEL
C   ***********************************************************************
C          PROGRAMME FOR SOLVING  NO WEAPON LIMITATION MODEL
        DIMENSION A(30,30),B(30),C(30),PSOL(30),DSOL(30),RW(600),IW(6
        14),IT(10),AT(10)
        READ(20,*)N,M1,M2
C       READ(20,*)((A(I,J),J=1,N),I=1,M1+M2)
C       GO TO 20
        DO 33 I=1,M1+M2
        READ(20,*)(A(I,J),J=1,N)
C       TYPE *,(A(I,J),J=1,N)
33      CONTINUE
        PRINT 22
22      FORMAT(5X,'*** DISTANCE MATRIX READ IN TO THE PROGRAM ***')
        PRINT 11,((A(I,J),J=1,N),I=1,M1+M2)
        READ(20,*)(IT(I),I=1,6)
        READ(20,*)(AT(I),I=1,5)
        DO 1 I=1,M1+M2
        DO 1 J=1,N
        DO 4 K=1,5
        K1=K
        IA=A(I,J)*66.*1.6
        IF(IA.GE.IT(K).AND.IA.LE.IT(K+1)) GO TO 2
4       CONTINUE
        GO TO 1
2       A(I,J)=-AT(K1)
1       CONTINUE
        PRINT 23
23      FORMAT(//5X,'*** EFFECTIVENESS MATRIX COMPUTED ***')
        PRINT 11,((A(I,J),J=1,N),I=1,M1+M2)
11      FORMAT(/2X,20F6.2)
        READ(20,*)(B(I),I=1,M1+M2)
        TYPE *,B
        READ(20,*)(C(I),I=1,N)
        TYPE *,C
        CALL ZX3LP(A,30,B,C,N,M1,M2,S,PSOL,DSOL,RW,IW,IER)
        PRINT 27
27      FORMAT(5X,'*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***'//)
        DO 24 I=1,N
24      PRINT 25,I,PSOL(I)
25      FORMAT(8X,'X(',I2,')','-------->',F10.4)
        PRINT 26,S
26      FORMAT(5X//,'VALUE OF THE OBJECTIVE FUNCTION =',F10.4)
        STOP;CALL UERTST;CALL ZX1LP;END
```

*** DISTANCE MATRIX READ IN TO THE PROGRAM ***

0.00	0.90	1.10	1.20	0.40	1.40	1.40	0.70	1.80	1.90	2.50	1.00	0.40	1.50	1.20	0.60	2.00	1.50	1.20
0.90	0.00	1.80	1.10	1.30	1.50	2.30	3.50	1.60	1.70	1.00	1.50	5.50	0.60	1.80	1.10	2.40	1.20	2.40
1.10	1.80	0.00	1.50	0.75	1.50	0.40	1.60	1.90	1.90	1.20	1.90	1.40	2.40	3.50	0.85	1.40	1.80	2.10
1.20	1.10	1.50	0.00	1.30	0.40	1.85	0.80	0.60	0.70	1.45	1.20	1.10	1.30	1.30	0.75	1.45	3.50	1.30
0.40	1.30	0.75	1.30	0.00	1.50	1.10	1.00	1.80	2.00	0.45	1.40	0.75	1.90	0.95	0.65	1.80	1.60	1.60
1.40	1.50	1.50	0.40	1.50	0.00	1.80	1.10	0.50	0.50	1.70	1.50	1.40	1.70	1.20	0.90	1.10	0.50	1.60
1.40	2.30	0.40	1.80	1.10	1.80	0.00	2.00	2.20	2.20	1.50	2.40	1.70	2.80	0.55	1.20	1.40	2.10	2.60
0.70	0.35	1.60	0.80	1.00	1.10	2.00	0.00	1.30	1.50	0.90	0.50	0.40	0.80	1.50	0.80	0.21	1.00	0.65
1.80	1.60	1.90	0.60	1.80	0.50	2.20	1.30	0.00	0.20	2.00	1.60	1.70	1.60	1.70	1.20	1.40	0.35	1.60
1.90	1.70	1.90	0.70	2.00	0.50	2.20	1.50	2.00	0.00	2.20	1.80	1.80	1.80	1.70	1.30	1.20	0.55	1.90
2.50	1.00	1.20	1.40	0.45	1.70	1.50	0.90	2.00	2.20	0.00	1.10	0.50	1.60	1.40	0.90	2.20	1.70	1.30
1.00	1.50	1.90	1.20	1.40	1.50	2.40	0.50	1.60	1.80	1.10	0.00	0.70	0.45	2.00	1.20	0.20	1.30	0.20
0.40	0.50	1.40	1.10	0.75	1.40	1.70	0.40	1.70	1.80	0.50	0.70	0.00	1.10	1.50	0.70	2.10	1.30	0.85
1.50	0.60	2.40	1.30	1.90	1.70	2.80	0.80	1.60	1.80	1.60	0.45	1.10	0.00	2.40	1.50	2.80	1.30	0.30
1.20	1.80	3.00	1.30	0.95	1.20	0.50	1.50	1.70	1.70	1.40	2.00	1.50	2.40	0.00	0.80	1.00	1.60	2.20
0.60	1.10	0.80	0.70	0.60	0.90	1.20	0.80	1.20	1.30	0.90	1.20	0.75	1.50	0.80	0.00	1.40	1.00	1.40
2.00	2.40	1.40	1.40	1.80	1.10	1.40	2.10	1.40	1.20	2.20	2.50	2.10	2.80	1.00	1.40	0.00	1.50	2.60
1.50	1.20	1.80	0.35	1.60	0.50	2.10	1.00	0.35	0.55	1.70	1.30	1.30	1.30	1.60	1.00	1.50	0.00	1.30
1.20	0.30	2.10	1.30	1.60	1.60	2.60	6.50	1.60	1.90	1.30	0.20	0.85	0.30	2.20	1.40	2.60	1.30	0.00
1.10	1.50	0.80	0.80	1.00	0.65	1.10	1.20	1.10	1.20	1.30	1.60	1.20	1.90	0.55	0.50	0.90	1.00	1.80

*** EFFECTIVENESS MATRIX COMPUTED ***

-1.00	-0.70	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30
-0.70	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.30	-0.30	-0.30	-0.30	0.00	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30
-0.30	-0.30	-1.00	-0.30	-0.70	-0.30	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.70	-0.30	-0.30	-0.30
-0.30	-0.30	-0.30	-1.00	-0.30	-0.90	-0.30	-0.70	-0.70	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	0.00	-0.30
-0.90	-0.30	-0.70	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.70	-0.30	-0.70	-0.70	-0.30	-0.30	-0.30
-0.30	-0.30	-0.30	-0.90	-0.30	-1.00	-0.30	-0.30	-0.70	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30
-0.30	-0.30	-0.90	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30
-0.70	-0.90	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.70	-0.70	-0.90	-0.70	-0.30	-0.70	-0.90	-0.30	-0.70
-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-1.00	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.90	-0.30
-0.30	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30
-0.30	-0.30	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.30	-0.30	-1.00	-0.30	-0.70	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30
-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-1.00	-0.70	-0.90	-0.30	-0.30	-0.90	-0.30	-0.90
-0.90	-0.70	-0.30	-0.30	-0.70	-0.30	-0.30	-0.90	-0.30	-0.30	-0.70	-0.70	-1.00	-0.30	-0.30	-0.70	-0.30	-0.30	-0.70
-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.30	-0.30	-0.30	-0.90	-0.30	-1.00	-0.30	-0.30	-0.30	-0.30	-0.90
-0.30	-0.30	0.00	-0.30	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.70	-0.30	-0.30	-0.30
-0.70	-0.30	-0.70	-0.70	-0.70	-0.70	-0.30	-0.70	-0.30	-0.30	-0.70	-0.30	-0.70	-0.30	-0.70	-1.00	-0.30	-0.30	-0.30
-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.30	-0.30
-0.30	-0.30	-0.30	-0.90	-0.30	-0.70	-0.30	-0.30	-0.90	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-1.00	-0.30
-0.30	-0.90	-0.30	-0.30	-0.30	-0.30	-0.30	0.00	-0.30	-0.30	-0.30	-0.90	-0.70	-0.90	-0.30	-0.30	-0.30	-0.30	-1.00
-0.30	-0.30	-0.70	-0.70	-0.30	-0.70	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.70	-0.70	-0.70	-0.30	-0.30

*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

X(1)---------> 9.2754
X(2)---------> 0.0009

```
X( 3)---------->     0.0000
X( 4)---------->     0.0000
X( 5)---------->     0.0000
X( 6)---------->     0.0000
X( 7)---------->     0.0000
X( 8)---------->     0.0000
X( 9)---------->     0.0000
X(10)---------->    13.9130
X(11)---------->     0.0000
X(12)---------->     0.0000
X(13)---------->     0.0000
X(14)---------->     0.0000
X(15)---------->     0.0000
X(16)---------->    10.4348
X(17)---------->    13.9130
X(18)---------->     0.0000
X(19)---------->     0.0000
X(20)---------->     0.0000

VALUE OF THE OBJECTIVE FUNCTION =  -47.5362
```

```
 X( 3)--------->     0.0000
 X( 4)--------->    12.0000
 X( 5)--------->    24.0000
 X( 6)--------->    24.0000
 X( 7)--------->    12.0000
 X( 8)--------->    24.0000
 X( 9)--------->     0.0000
 X(10)--------->    24.0000
 X(11)--------->     0.0000
 X(12)--------->     5.8537
 X(13)--------->    24.0000
 X(14)--------->     0.0000
 X(15)--------->    12.0000
 X(16)--------->    24.0000
 X(17)--------->    24.0000
 X(18)--------->     0.0000
 X(19)--------->    10.2439
 X(20)--------->    12.0000

VALUE OF THE OBJECTIVE FUNCTION = -266.3415
```

*** DISTANCE MATRIX READ IN TO THE PROGRAM ***

0.00	9.00	11.00	12.00	4.00	14.00	14.00	7.00	18.00	19.00	2.50	10.00	4.00	15.00	12.00	6.00	20.50	15.00	12.00	11
9.00	0.00	18.50	11.00	13.00	15.00	23.00	3.50	16.00	17.50	10.50	1.50	5.50	6.00	18.50	11.00	24.00	12.50	3.00	15
11.00	18.50	0.00	15.00	7.50	15.00	4.00	16.00	19.00	19.00	12.00	19.50	14.00	24.00	3.50	8.50	14.00	18.00	21.50	8
12.00	11.00	15.00	0.00	13.50	4.00	18.50	8.00	6.00	7.00	14.50	12.00	11.00	13.00	13.50	7.50	14.50	3.50	13.00	8
4.00	13.00	7.50	13.50	0.00	15.00	11.00	10.50	18.50	20.00	4.50	14.00	7.50	19.50	9.50	6.50	18.50	16.50	16.00	10
14.00	15.00	15.00	4.00	15.00	0.00	18.00	11.50	5.00	5.00	17.00	15.50	14.50	17.00	12.00	9.00	11.00	5.00	16.50	6
14.00	23.00	4.00	18.50	11.00	18.00	0.00	20.00	22.50	22.50	15.00	24.00	17.50	28.00	5.50	12.50	14.50	21.50	26.00	11
7.00	3.50	16.00	8.00	10.50	11.50	20.00	0.00	13.50	15.00	9.50	5.00	4.00	8.50	15.50	8.00	21.00	10.00	6.50	12
18.00	16.00	19.00	6.00	18.50	5.00	22.50	13.50	0.00	2.00	20.50	16.00	17.00	16.00	17.00	12.50	14.50	3.50	16.50	11
19.00	17.50	19.00	7.00	20.00	5.00	22.50	15.00	2.00	0.00	22.00	18.00	18.50	18.50	17.00	13.50	12.50	5.50	19.00	12
2.50	10.50	12.00	14.50	14.50	17.00	15.00	9.50	20.50	22.00	0.00	11.50	5.00	16.50	14.00	9.00	22.50	17.50	13.00	13
10.00	1.50	19.50	12.00	14.00	15.50	24.00	5.00	16.00	18.00	11.50	0.00	7.00	4.50	20.50	12.50	25.00	13.00	2.00	16
4.00	5.50	14.00	11.00	7.50	14.50	17.50	4.00	17.00	18.50	5.00	7.00	0.00	11.50	15.00	7.50	21.50	13.50	8.50	12
15.00	6.00	24.00	13.00	19.50	17.00	28.00	8.50	16.00	18.50	16.50	4.50	11.50	0.00	24.00	15.50	28.00	13.00	3.00	19
12.00	18.50	3.50	13.50	9.50	12.00	5.50	15.50	17.00	17.00	14.00	20.50	15.00	24.00	0.00	8.00	10.50	16.50	22.00	5
6.00	11.00	8.50	7.50	6.50	9.00	12.50	8.00	12.50	13.50	9.00	12.50	7.50	15.50	8.00	0.00	14.50	10.50	14.00	5
20.50	24.00	14.00	14.50	18.50	11.00	14.50	21.00	14.50	12.50	22.50	25.00	21.50	28.00	10.50	14.50	0.00	15.50	26.00	9
15.00	12.50	18.00	3.50	16.50	5.00	21.50	10.00	3.50	5.50	17.50	13.00	13.50	13.00	16.50	10.50	15.50	0.00	13.00	10
12.00	3.00	21.50	13.00	16.00	16.50	26.00	6.50	16.50	19.00	13.00	2.00	8.50	3.00	22.00	14.00	26.00	13.00	0.00	18
11.00	15.50	8.00	8.00	10.00	6.50	11.00	12.00	11.00	12.00	13.50	16.50	12.50	19.50	5.50	5.00	9.50	10.50	18.00	0

*** EFFECTIVENESS MATRIX COMPUTED ***

-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1

*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

```
X( 1)---------->   21.0000
X( 2)---------->   1[illegible].2439
```

```
C ********************************************************************
C       THIS PROGRAM IS FOR A LIMITED WEAPON  MODEL
C **********************************************************************
C       UNPREPAREDNESS OPTIMIZATION
        DIMENSION A(30,40),B(30),C(40),PSOL(40),DSOL(50),RW(600),IW(6
       17),IT(10),AT(10)
        READ(20,*)N,M1,M2
C       READ(20,*)((A(I,J),J=1,N),I=1,M1+M2)
C       GO TO 26
        DO 33 I=1,M1+M2-1
        READ(20,*)(A(I,J),J=1,20)
C       TYPE *,(A(I,J),J=1,N)
 33     CONTINUE
        PRINT 72
 72     FORMAT(5X,'*** DISTANCE MATRIX READ IN TO THE PROGRAM ***')
        PRINT 11,((A(I,J),J=1,20),I=1,M1+M2)
        READ(20,*)(IT(I),I=1,6)
        READ(20,*)(AT(I),I=1,5)
        DO 1 I=1,M1+M2
        DO 1 J=1,20
        DO 4 K=1,5
        K1=K
        IA=A(I,J)*66.*1.6
        IF(IA.GE.IT(K).AND.IA.LE.IT(K+1)) GO TO 2
 4      CONTINUE
        GO TO 1
 2      A(I,J)=-AT(K1)
 1      CONTINUE
        DO 9 I=1,20
        DO 9 J=1,20
        A(I,J+20)=0
        IF(I.EQ.J) A(I,J+20)=-1
 9      CONTINUE
        READ(20,*)(A(21,I),I=1,40)
        PRINT 23
 23     FORMAT(//5X,'*** EFFECTIVENESS MATRIX COMPUTED ***')
        PRINT 11,((A(I,J),J=1,N),I=1,M1+M2)
 11     FORMAT(/2X,20F6.2)
        READ(20,*)(B(I),I=1,M1+M2)
        PRINT 37,(B(I),I=1,M1+M2)
 37     FORMAT(5X,'RIGHTHAND SIDE VECTOR READ IN'/(5X,10F10.4))
        READ(20,*)(C(I),I=1,N)
        PRINT 38,(C(I),I=1,N)
 38     FORMAT(5X,'COEFFICIENTS IN THE OBJECTIVE FUNCTION'/(5X,10F10.4))
        CALL ZX3LP(A,30,B,C,N,M1,M2,S,PSOL,DSOL,RW,IW,IER)
        PRINT 27
 27     FORMAT(5X,'*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***'//)
        DO 24 I=1,N
 24     PRINT 25,I,PSOL(I)
 25     FORMAT(5X,'X(',I2,')','-------->',F10.4)
        PRINT 26,S
 26     FORMAT(5X//,'VALUE OF THE OBJECTIVE FUNCTION =',F10.4)
        STOP;CALL UERSET;CALL ZX1LP;END
```

```
RIGHTHAND SIDE VECTOR READ IN
   -24.0000   -12.0000     0.0000   -12.0000   -24.0000   -24.0000   -12.0000   -24.0000     1.0000   -24.0000
     0.0000   -12.0000   -24.0000     0.0000   -12.0000   -24.0000   -24.0000     0.0000   -1[illegible].0000   -12.0000
    45.0000
COEFFICIENTS IN THE OBJECTIVE FUNCTION
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     1.0000     0.0000
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     1.0000     0.0000
   -20.0000   -15.0000    -9.0000   -14.0000   -19.0000   -20.0000   -13.0000   -16.0000   -[illegible].0000   -20.0000
   -10.0000   -14.0000   -17.0000    -3.0000   -15.0000   -18.0000   -19.0000   -1[illegible].0000   -14.0000   -14.0000
*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

  X( 1)-------->    10.0000
  X( 2)-------->     0.0000
  X( 3)-------->     0.0000
  X( 4)-------->     0.0000
  X( 5)-------->     0.0000
  X( 6)-------->     0.0000
  X( 7)-------->     0.0000
  X( 8)-------->     0.0000
  X( 9)-------->     0.0000
  X(10)-------->    15.0000
  X(11)-------->     0.0000
  X(12)-------->     0.0000
  X(13)-------->     0.0000
  X(14)-------->     0.0000
  X(15)-------->     0.0000
  X(16)-------->    11.2500
  X(17)-------->     8.7500
  X(18)-------->     0.0000
  X(19)-------->     0.0000
  X(20)-------->     0.0000
  X(21)-------->     0.0000
  X(22)-------->     0.0000
  X(23)-------->     0.0000
  X(24)-------->     0.0000
  X(25)-------->     0.0000
  X(26)-------->     0.0000
  X(27)-------->     0.0000
  X(28)-------->     0.0000
  X(29)-------->     0.0000
  X(30)-------->     0.0000
  X(31)-------->     0.0000
  X(32)-------->     0.0000
  X(33)-------->     0.0000
  X(34)-------->     0.0000
  X(35)-------->     0.0000
  X(36)-------->     0.0000
  X(37)-------->     4.3750
  X(38)-------->     0.0000
  X(39)-------->     0.0000
  X(40)-------->     0.0000

VALUE OF THE OBJECTIVE FUNCTION =  -83.1250
```

```
RIGHTHAND SIDE VECTOR READ IN
   -24.0000   -12.0000     0.0000   -12.0000   -24.0000   -24.0000   -12.0000   -2[illegible]0000     0.0000   -24.0000
     0.0000   -12.0000   -24.0000     0.0000   -12.0000   -24.0000   -24.0000   [illegible]0000   -12.0000   -12.0000
    45.0000
COEFFICIENTS IN THE OBJECTIVE FUNCTION
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000   [illegible]0000     0.0000     0.0000
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000   [illegible]0000     0.0000     0.0000
    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000   -[illegible]0000    -1.0000    -1.0000
    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000    -1.0000   -[illegible]0000    -1.0000    -1.0000
*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

      X( 1)---------->   10.0000
      X( 2)---------->    0.0000
      X( 3)---------->    0.0000
      X( 4)---------->    0.0000
      X( 5)---------->    0.0000
      X( 6)---------->    0.0000
      X( 7)---------->    0.0000
      X( 8)---------->    0.0000
      X( 9)---------->    0.0000
      X(10)---------->   15.0000
      X(11)---------->    0.0000
      X(12)---------->    0.0000
      X(13)---------->    0.0000
      X(14)---------->    0.0000
      X(15)---------->    0.0000
      X(16)---------->   11.2500
      X(17)---------->    8.7500
      X(18)---------->    0.0000
      X(19)---------->    0.0000
      X(20)---------->    0.0000
      X(21)---------->    0.0000
      X(22)---------->    0.0000
      X(23)---------->    0.0000
      X(24)---------->    0.0000
      X(25)---------->    0.0000
      X(26)---------->    0.0000
      X(27)---------->    0.0000
      X(28)---------->    0.0000
      X(29)---------->    0.0000
      X(30)---------->    0.0000
      X(31)---------->    0.0000
      X(32)---------->    0.0000
      X(33)---------->    0.0000
      X(34)---------->    0.0000
      X(35)---------->    0.0000
      X(36)---------->    0.0000
      X(37)---------->    4.3750
      X(38)---------->    0.0000
      X(39)---------->    0.0000
      X(40)---------->    0.0000

VALUE OF THE OBJECTIVE FUNCTION =    -4.3750
```

```
RIGHTHAND SIDE VECTOR READ IN
  -24.0000  -12.0000    0.0000  -12.0000  -24.0000  -24.0000  -12.0000  [illegible]    0.0000  -24.0000
    0.0000  -12.0000  -24.0000    0.0000  -12.0000  -24.0000  -24.0000  [illegible]  -12.0000  -12.0000
   45.0000
COEFFICIENTS IN THE OBJECTIVE FUNCTION
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  -32.0000  -16.0000   -8.0000  -16.0000  -32.0000  -32.0000  -16.0000  [illegible]   -4.0000  -32.0000
   -8.0000  -16.0000  -32.0000   -2.0000  -16.0000  -32.0000  -32.0000  [illegible]  -16.0000  -16.0000
*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

    X( 1)---------->   10.0000
    X( 2)---------->    0.0000
    X( 3)---------->    0.0000
    X( 4)---------->    0.0000
    X( 5)---------->    0.0000
    X( 6)---------->    0.0000
    X( 7)---------->    0.0000
    X( 8)---------->    0.0000
    X( 9)---------->    0.0000
    X(10)---------->   15.0000
    X(11)---------->    0.0000
    X(12)---------->    0.0000
    X(13)---------->    0.0000
    X(14)---------->    0.0000
    X(15)---------->    0.0000
    X(16)---------->   11.2500
    X(17)---------->    8.7500
    X(18)---------->    0.0000
    X(19)---------->    0.0000
    X(20)---------->    0.0000
    X(21)---------->    0.0000
    X(22)---------->    0.0000
    X(23)---------->    0.0000
    X(24)---------->    0.0000
    X(25)---------->    0.0000
    X(26)---------->    0.0000
    X(27)---------->    0.0000
    X(28)---------->    0.0000
    X(29)---------->    0.0000
    X(30)---------->    0.0000
    X(31)---------->    0.0000
    X(32)---------->    0.0000
    X(33)---------->    0.0000
    X(34)---------->    0.0000
    X(35)---------->    0.0000
    X(36)---------->    0.0000
    X(37)---------->    4.3750
    X(38)---------->    0.0000
    X(39)---------->    0.0000
    X(40)---------->    0.0000

VALUE OF THE OBJECTIVE FUNCTION = -139.9999
```

```
RIGHTHAND SIDE VECTOR READ IN   -12.0000  -24.0000  -24.0000  -12.0000  -24.0000    0.0000  -24.0000
  -24.0000  -12.0000    0.0000    0.0000  -12.0000  -24.0000  -24.0000    0.0000  -12.0000  -12.0000
    0.0000  -12.0000  -24.0000
  250.0000
COEFFICIENTS IN THE OBJECTIVE FUNCTION
                                0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000
   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000
   -1.0000   -1.0000   -1.0000
*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

     X( 1)---------->     7.6585
     X( 2)---------->    10.2439
     X( 3)---------->     0.0000
     X( 4)---------->    12.0000
     X( 5)---------->    24.0000
     X( 6)---------->    24.0000
     X( 7)---------->    12.0000
     X( 8)---------->    24.0000
     X( 9)---------->     0.0000
     X(10)---------->    24.0000
     X(11)---------->     0.0000
     X(12)---------->     5.9537
     X(13)---------->    24.0000
     X(14)---------->     0.0000
     X(15)---------->    12.0000
     X(16)---------->    24.0000
     X(17)---------->    24.0000
     X(18)---------->     0.0000
     X(19)---------->    10.2439
     X(20)---------->    12.0000
     X(21)---------->    16.3415
     X(22)---------->     0.0000
     X(23)---------->     0.0000
     X(24)---------->     0.0000
     X(25)---------->     0.0000
     X(26)---------->     0.0000
     X(27)---------->     0.0000
     X(28)---------->     0.0000
     X(29)---------->     0.0000
     X(30)---------->     0.0000
     X(31)---------->     0.0000
     X(32)---------->     0.0000
     X(33)---------->     0.0000
     X(34)---------->     0.0000
     X(35)---------->     0.0000
     X(36)---------->     0.0000
     X(37)---------->     0.0000
     X(38)---------->     0.0000
     X(39)---------->     0.0000
     X(40)---------->     0.0000

VALUE OF THE OBJECTIVE FUNCTION =   -16.3415
```

```
RIGHTHAND SIDE VECTOR READ IN
  -24.0000   -12.0000     0.0000   -12.0000   -24.0000   -24.0000   -12.0000   -2[illegible].0000   [illegible].0000   -24.0000
    0.0000   -12.0000   -24.0000     0.0000   -12.0000   -24.0000   -24.0000   [illegible].0000   -1[illegible].0000   -12.0000
  250.0000
COEFFICIENTS IN THE OBJECTIVE FUNCTION
    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000   [illegible].0000   [illegible].0000     0.0000
    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000   [illegible].0000   [illegible].0000     0.0000
  -2[illegible].0000   -15.0000    -9.0000   -14.0000   -19.0000   -20.0000   -13.0000   -1[illegible].0000   [illegible].0000   -20.0000
  -10.0000   -14.0000   -17.0000    -3.0000   -15.0000   -18.0000   -19.0000   -1[illegible].0000   -[illegible].0000   -14.0000
*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

     X( 1)--------->    24.0000
     X( 2)--------->    10.2439
     X( 3)--------->     0.0000
     X( 4)--------->     7.6585
     X( 5)--------->    24.0000
     X( 6)--------->    24.0000
     X( 7)--------->     0.0000
     X( 8)--------->    24.0000
     X( 9)--------->     0.0000
     X(10)--------->    24.0000
     X(11)--------->     0.0000
     X(12)--------->     5.8537
     X(13)--------->    24.0000
     X(14)--------->     0.0000
     X(15)--------->    12.0000
     X(16)--------->    24.0000
     X(17)--------->    24.0000
     X(18)--------->     0.0000
     X(19)--------->    10.2439
     X(20)--------->    12.0000
     X(21)--------->     0.0000
     X(22)--------->     0.0000
     X(23)--------->     0.0000
     X(24)--------->     4.3415
     X(25)--------->     0.0000
     X(26)--------->     0.0000
     X(27)--------->    12.0000
     X(28)--------->     0.0000
     X(29)--------->     0.0000
     X(30)--------->     0.0000
     X(31)--------->     0.0000
     X(32)--------->     0.0000
     X(33)--------->     0.0000
     X(34)--------->     0.0000
     X(35)--------->     0.0000
     X(36)--------->     0.0000
     X(37)--------->     0.0000
     X(38)--------->     0.0000
     X(39)--------->     0.0000
     X(40)--------->     0.0000

VALUE OF THE OBJECTIVE FUNCTION = -216.7805
```

```
   -24.0000   -12.0000     0.0000   -12.0000   -24.0000   -24.0000   -12.0000   -24.0000     0.0000   -24.0000
     0.0000   -12.0000   -24.0000     0.0000   -12.0000   -24.0000   -24.0000     0.0000   -12.0000   -12.0000
   250.0000
 COEFFICIENTS IN THE OBJECTIVE FUNCTION
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   -32.0000   -16.0000    -8.0000   -16.0000   -32.0000   -32.0000   -16.0000   -32.0000    -4.0000   -32.0000
    -8.0000   -16.0000   -32.0000    -2.0000   -16.0000   -32.0000   -32.0000    -8.0000   -16.0000   -16.0000
 *** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

      X( 1)---------->    24.0000
      X( 2)---------->    10.2439
      X( 3)---------->     0.0000
      X( 4)---------->     0.0000
      X( 5)---------->    24.0000
      X( 6)---------->    24.0000
      X( 7)---------->     7.6585
      X( 8)---------->    24.0000
      X( 9)---------->     0.0000
      X(10)---------->    24.0000
      X(11)---------->     0.0000
      X(12)---------->     5.8537
      X(13)---------->    24.0000
      X(14)---------->     0.0000
      X(15)---------->    12.0000
      X(16)---------->    24.0000
      X(17)---------->    24.0000
      X(18)---------->     0.0000
      X(19)---------->    10.2439
      X(20)---------->    12.0000
      X(21)---------->     0.0000
      X(22)---------->     0.0000
      X(23)---------->     0.0000
      X(24)---------->    12.0000
      X(25)---------->     0.0000
      X(26)---------->     0.0000
      X(27)---------->     4.3415
      X(28)---------->     0.0000
      X(29)---------->     0.0000
      X(30)---------->     0.0000
      X(31)---------->     0.0000
      X(32)---------->     0.0000
      X(33)---------->     0.0000
      X(34)---------->     0.0000
      X(35)---------->     0.0000
      X(36)---------->     0.0000
      X(37)---------->     0.0000
      X(38)---------->     0.0000
      X(39)---------->     0.0000
      X(40)---------->     0.0000

 VALUE OF THE OBJECTIVE FUNCTION = -261.4634
```

```
C     AND ALL OTHER PLACES IN A RADIUS OF "70" KMS.
C***************************************************************************
      DIMENSION A1(50,200),B(42),C(200),PSOL(40),DSOL(50),RW(2000),IW(
     1150),IT(10),AT(10),I1(20),A(20,20),I3(20,20),I4(20)
      DIMENSION A2(20,20),B1(20)
      NT=23; NT INDICATES THE DATA FILE
      READ(NT,*)N,M1,M2,DIST,ICR
C     N: NO OF UNKNOWNS;M1:NO OF INEQUALITY CONSTRAINTS
C     M2:NO OF EQUALITY CONSTRAINTS;DIST: RADIUS CHOSEN FOR
C     FORMING SUBSETS AROUND CRITICAL POINTS
C     ICR: PLACES CHOSEN ACCORDING TO THE VALUE OF ICR
      READ(NT,*)(C(I),I=1,20)
      J4=0
      DO 12 I=1,20
      IF(C(I).GE.ICR) GO TO 12
      J4=J4+1
      I1(J4)=I
12    CONTINUE
      PRINT 13,(I1(I),I=1,J4)
13    FORMAT(2X,"SUBSET CHOSEN FOR ATTACK"/(5X,10I5))
      READ(NT,*)((A(I,J),J=1,20),I=1,20)
      READ(NT,*)(IT(I),I=1,5)
      READ(NT,*)(AT(I),I=1,5)
      READ(NT,*)(B1(I),I=1,20)
C     FORMATION OF SUMMATION d1 OVER THE SUBSET
      DO 88 I=1,J4
88    SU=SU+B(I1(I))
C     READ(NT,*)(C(I),I=1,N)
C     PRINT 22
C22   FORMAT(5X,"*** DISTANCE MATRIX READ IN TO THE PROGRAM ***")
C     PRINT 11,((A(I,J),J=1,20),I=1,20)
      DO 1 I=1,20
      DO 1 J=1,20
      IA=A(I,J)*66.*1.6
      A(I,J)=IA
      DO 4 K=1,5
      K1=K
      IF(IA.GE.IT(K).AND.IA.LE.IT(K+1)) GO TO 2
4     CONTINUE
      GO TO 1
2     A2(I,J)=-AT(K1)
1     CONTINUE
C     PRINT 23
23    FORMAT(//5X,"*** EFFECTIVENESS MATRIX COMPUTED ***")
C     PRINT 11,((A2(I,J),J=1,20),I=1,20)
C11   FORMAT(/2X,10F10.1)
C     PRINT 47,(B(I),I=1,M1+M2)
C47   FORMAT(5X,"RIGHTHAND SIDE VECTOR READ IN"/(5X,10F10.4))
      DO 48 L=1,J4
      JI=I1(L)
      J6=0
      DO 47 J=1,20
      IF(A(JI,J).LE.100) GO TO 54
      GO TO 47
54    J6=J6+1
      I3(L,J6)=J
47    CONTINUE
      I1(L)=J6
C     PRINT 14,JI,(I3(L,I),I=1,J6)
C14   FORMAT(2X,"SUBSET CORRESPONDING TO"1X,I3/(5X,10I5))
48    CONTINUE
      K=0
      DO 64 L=1,20
      DO 65 I=1,J4
      DO 65 J=1,I1(I)
      IF(I3(I,J).EQ.L) GO TO 66
65    CONTINUE
      GO TO 64
66    K=K+1
      I4(K)=L
64    CONTINUE
      PRINT 14,(I4(I),I=1,K)
14    FORMAT(2X,"PLACES FOR DEFENDING THE SUBSET "/(5X,10I5))
      J8=J4*K+2*K+1;J9=2*K+2;J7=J4*K
      B(J9)=-50
C     J9 IS THE NO OF VARIABLES;J8 IS THE NO OF CONSTRAINTS
      DO 9 I=1,J9
      C(I)=0
      DO 9 J=1,J8
9     A1(I,J)=0
      DO 10 I=1,K
      A1(I,J7+I)=-1.
      I0=I
      L4=J4*(I0-1)
      DO 10 J=1,J4
      A1(J9+1,J)=1.
10    A1(I,J+L4)=A2(I4(I),I1(J))
```

```
      [illegible]
15    [illegible]
      DO 17 I=1,J7
17    A1(J9,I)=-1.
      A1(J9,J7+1)=-1.
C     PRINT 18,((A1(I,J),J=1,J8),I=1,J9)
C18   FORMAT(2X,30F4.1)
      DO 19 I=1,K
      B(K+I)=0
19    B(I)=B1(I4(I))
      B(2*K+1)=B1(21)
      IER=0;M1=J9;M2=0;N=J8
      DO 22 I=1,K
22    C(J7+I)=-1
      PRINT 38,(C(J7+I),I=1,K)
38    FORMAT(5X,'COEFFICIENTS IN THE OBJECTIVE FUNCTION'/(5X,10F10.4))
      CALL ZX3LP(A1,50,B,C,N,M1,M2,S,PSOL,DSOL,RW,IW,IER)
      PRINT 27
27    FORMAT(5X,'*** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***'//)
      DO 24 I=1,K
      J7I=J7+I
24    PRINT 25,I4(I),PSOL(J7I)
25    FORMAT(8X,'X(',I3,')','---------->',F10.4)
      PRINT 26,S
26    FORMAT(5X//,'VALUE OF THE OBJECTIVE FUNCTION =',F10.4)
100   CONTINUE
      STOP;CALL UERTST;CALL ZX1LP;END
```

```
PLACES FOR [illegible]
    1     2     3     4     5     6     8     9    10    11
   12    13    14    15    16    17    18    19    20
 COEFFICIENTS IN THE OBJECTIVE FUNCTION
   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000
   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000   -1.0000
   -1.0000   -1.0000
 *** PRIMAL SOLUTION OBTAINED FROM ZX3LP ***

     X(  1)--------->    14.1176
     X(  2)--------->     6.0000
     X(  3)--------->     0.0000
     X(  4)--------->     6.0000
     X(  5)--------->    12.6316
     X(  6)--------->    12.0000
     X(  8)--------->    12.6316
     X(  9)--------->     0.0000
     X( 10)--------->    14.1176
     X( 11)--------->     0.0000
     X( 12)--------->     9.2308
     X( 13)--------->    14.1176
     X( 14)--------->     0.0000
     X( 15)--------->     7.0588
     X( 16)--------->    14.1176
     X( 17)--------->    10.4615
     X( 18)--------->     0.0000
     X( 19)--------->     6.3158
     X( 20)--------->     7.0588

 VALUE OF THE OBJECTIVE FUNCTION = -153.0595
```

```
C ***********************************************************************
       THIS OUTPUT IS FOR FIXED COST MODEL.
       MAXIMUM DEFENCE CENTRES = 10.
       CPU TIME = 0.69.
C ***********************************************************************
  0   0
    ROWS X COLUMNS and NO OF INTEGERS

     42    41            10
  INPUT TABLE ECHO: CONSTRAINT VALUE LEFT SIDE
CONTINUOUS SOLUTION  COMPLETE
OBJECTIVE FUNCTION=  0.3100000D+03AT ITERATION      0
STARTING VARIABLES:X(I)
           1         .1000D+01
           2         .1000D+01
           3         .1000D+01
           4         .1000D+01
           5         .1000D+01
           6         .1000D+01
           7         .1000D+01
           8         .1000D+01
           9         .1000D+01
          10         .1000D+01
          11         .1000D+02
          12         .1000D+02
          13         .1000D+02
          14         .1000D+02
          15         .1000D+02
          16         .1000D+02
          17         .1000D+02
          18         .1000D+02
          19         .1000D+02
          20         .1000D+02
          21         .1000D+02
          22         .1000D+02
          23         .1000D+02
          24         .1000D+02
          25         .1000D+02
          26         .1000D+02
          27         .1000D+02
          28         .1000D+02
          29         .1000D+02
          30         .1000D+02
          31         .1000D+02
          32         .1000D+02
          33         .1000D+02
          34         .1000D+02
          35         .1000D+02
          36         .1000D+02
          37         .1000D+02
          38         .1000D+02
          39         .1000D+02
          40         .1000D+02
  CONT SOLN IS INTEGER
  OPT ESTABLISHED
  END,ITER NO      0
```

```
C  ******************************************************************
        [illegible] COST [illegible].
        [illegible] = 8.
        [illegible] = 5.67.
C  ******************************************************************
   0    0
      ROWS X COLUMNS and NO OF INTEGERS

      42    41                              10
   INPUT TABLE ECHO: CONSTRAINT VALUE LEFT SIDE
 CONTINUOUS SOLUTION   COMPLETE
 OBJECTIVE FUNCTION=   0.3080000D+03AT ITERATION
 STARTING VARIABLES:X(I)
           1        .30000D+00
           2        .30000D+00
           3        .40000D+00
           4        .40000D+01
           5        .40000D+01
           6        .40000D+01
           7        .40000D+01
           8        .40000D+01
           9        .40000D+01
          10        .40000D+01
          11        .40000D+02
          12        .40000D+02
          13        .40000D+02
          14        .40000D+02
          15        .40000D+02
          16        .40000D+02
          17        .40000D+02
          18        .40000D+02
          19        .40000D+02
          20        .40000D+02
          21        .40000D+02
          22        .40000D+02
          23        .40000D+02
          24        .40000D+02
          25        .40000D+02
          26        .40000D+02
          27        .40000D+02
          28        .40000D+02
          29        .40000D+02
          30        .40000D+02
          31        .40000D+02
          32        .40000D+02
          33        .40000D+02
          34        .40000D+02
          35        .40000D+02
          36        .40000D+02
          37        .40000D+02
          38        .40000D+02
          39        .40000D+02
          40        .40000D+02
 OBJECTIVE FUNCTION=   0.2480000D+03AT ITERATION    107
 STARTING VARIABLES:X(I)
           1        .00000D+00
           2        .40000D+01
           3        .00000D+00
           4        .40000D+01
           5        .40000D+01
           6        .40000D+01
           7        .40000D+01
           8        .40000D+01
           9        .40000D+01
          10        .40000D+01
          11        .00000D+00
          12        .40000D+02
          13        .00000D+00
          14        .40000D+02
          15        .40000D+02
          16        .40000D+02
          17        .40000D+02
          18        .40000D+02
          19        .40000D+02
          20        .40000D+02
          21        .00000D+00
          22        .40000D+02
          23        .1188D-15
          24        .40000D+02
          25        .40000D+02
          26        .40000D+02
          27        .40000D+02
          28        .40000D+02
          29        .40000D+02
          30        .40000D+02
          31        .00000D+00
          32        .40000D+02
          33        .00000D+00
          34        .40000D+02
```

```
        35          .1000D+02
        36          .1000D+02
        37          .1000D+02
        38          .1000D+02
        39          .1000D+02
        40          .1000D+02
 OBJECTIVE FUNCTION=  0.2480000D+03AT ITERATION    137
 STARTING VARIABLES:X(I)
         1          .1000D+01
         2          .1000D+01
         3          .0000D+00
         4          .1000D+01
         5          .1000D+01
         6          .1000D+01
         7          .1000D+01
         8          .1000D+01
         9          .0000D+00
        10          .1000D+01
        11          .1000D+02
        12          .1000D+02
        13          .0000D+00
        14          .1000D+02
        15          .1000D+02
        16          .1000D+02
        17          .1000D+02
        18          .1000D+02
        19          .0000D+00
        20          .1000D+02
        21          .1000D+02
        22          .1000D+02
        23          .0000D+00
        24          .1000D+02
        25          .1000D+02
        26          .1000D+02
        27          .1000D+02
        28          .1000D+02
        29          .0000D+00
        30          .1000D+02
        31          .1000D+02
        32          .1000D+02
        33          .5551D-16
        34          .1000D+02
        35          .1000D+02
        36          .1000D+02
        37          .1000D+02
        38          .1000D+02
        39          .0000D+00
        40          .1000D+02
  OPT ESTABLISHED
  END.ITER NO   204
```

```
        MAXIMUM DEPTH OF [illegible] = 6.
        CPU TIME = 23.7.
 ******************************************************************
    0    0
    ROWS X COLUMNS and NO OF INTEGERS

      42     41                        10
  INPUT TABLE ECHO: CONSTRAINT VALUE LEFT SIDE
CONTINUOUS SOLUTION  COMPLETE
OBJECTIVE FUNCTION=  0.3050000D+03AT ITERATION
STARTING VARIABLES:X(I)
          1         .3000D+00
          2         .3000D+00
          3         .3000D+00
          4         .3000D+00
          5         .3000D+00
          6         .5000D+00
          7         .1000D+01
          8         .1000D+01
          9         .1000D+01
         10         .1000D+01
         11         .1000D+02
         12         .1000D+02
         13         .1000D+02
         14         .1000D+02
         15         .1000D+02
         16         .1000D+02
         17         .1000D+02
         18         .1000D+02
         19         .1000D+02
         20         .1000D+02
         21         .1000D+02
         22         .1000D+02
         23         .1000D+02
         24         .1000D+02
         25         .1000D+02
         26         .1000D+02
         27         .1000D+02
         28         .1000D+02
         29         .1000D+02
         30         .1000D+02
         31         .1000D+02
         32         .1000D+02
         33         .1000D+02
         34         .1000D+02
         35         .1000D+02
         36         .1000D+02
         37         .1000D+02
         38         .1000D+02
         39         .1000D+02
         40         .1000D+02
 OBJECTIVE FUNCTION=  0.1860000D+03AT ITERATION    962
 STARTING VARIABLES:X(I)
          1         .0000D+00
          2         .1000D+01
          3         .0000D+00
          4         .0000D+00
          5         .1000D+01
          6         .1000D+01
          7         .1000D+01
          8         .1000D+01
          9         .0000D+00
         10         .1000D+01
         11         .0000D+00
         12         .1000D+02
         13         .0000D+00
         14         .0000D+00
         15         .1000D+02
         16         .1000D+02
         17         .1000D+02
         18         .1000D+02
         19         .0000D+00
         20         .1000D+02
         21         .0000D+00
         22         .1000D+02
         23         .0000D+00
         24         .1388D-16
         25         .1000D+02
         26         .1000D+02
         27         .1000D+02
         28         .1000D+02
         29         .0000D+00
         30         .1000D+02
         31         .0000D+00
         32         .1000D+02
         33         .0000D+00
         34         .0000D+00
```

```
        35          .1000D+02
        36          .1000D+02
        37          .1000D+02
        38          .1000D+02
        39          .0000D+00
        40          .1000D+02
 OBJECTIVE FUNCTION=   0.18600000D+03AT ITERATION    979
 STARTING VARIABLES:X(I)
         1          .1000D+01
         2          .1000D+01
         3          .0000D+00
         4          .0000D+00
         5          .0000D+00
         6          .1000D+01
         7          .1000D+01
         8          .1000D+01
         9          .0000D+00
        10          .1000D+01
        11          .1000D+02
        12          .1000D+02
        13          .0000D+00
        14          .0000D+00
        15          .0000D+00
        16          .1000D+02
        17          .1000D+02
        18          .1000D+02
        19          .0000D+00
        20          .1000D+02
        21          .1000D+02
        22          .1000D+02
        23          .0000D+00
        24          .0000D+00
        25          .6245D-16
        26          .1000D+02
        27          .1000D+02
        28          .1000D+02
        29          .0000D+00
        30          .1000D+02
        31          .1000D+02
        32          .1000D+02
        33          .2776D-16
        34          .0000D+00
        35          .0000D+00
        36          .1000D+02
        37          .1000D+02
        38          .1000D+02
        39          .0000D+00
        40          .1000D+02
 OBJECTIVE FUNCTION=   0.18600000D+03AT ITERATION   1010
 STARTING VARIABLES:X(I)
         1          .1000D+01
         2          .1000D+01
         3          .0000D+00
         4          .1000D+01
         5          .0000D+00
         6          .0000D+00
         7          .1000D+01
         8          .1000D+01
         9          .0000D+00
        10          .1000D+01
        11          .1000D+02
        12          .1000D+02
        13          .0000D+00
        14          .1000D+02
        15          .0000D+00
        16          .0000D+00
        17          .1000D+02
        18          .1000D+02
        19          .0000D+00
        20          .1000D+02
        21          .1000D+02
        22          .1000D+02
        23          .3469D-16
        24          .1000D+02
        25          .2776D-16
        26          .0000D+00
        27          .1000D+02
        28          .1000D+02
        29          .0000D+00
        30          .1000D+02
        31          .1000D+02
        32          .1000D+02
        33          .0000D+00
        34          .1000D+02
        35          .0000D+00
        36          .2776D-16
        37          .1000D+02
        38          .1000D+02
        39          .0000D+00
```

```
 ********************************************************
        THIS OUTPUT IS FOR FIXED COST MODEL.
        MAXIMUM DEFENCE CENTERS ARE =5.
        CPU TIME = 27.43.
 ********************************************************
  0    0
   ROWS X COLUMNS and NO OF INTEGERS
                                          10
      42    41
  INPUT TABLE ECHO: CONSTRAINT VALUE LEFT SIDE
CONTINUOUS SOLUTION  COMPLETE
OBJECTIVE FUNCTION=  0.3050000D+03AT ITERATION       8
STARTING VARIABLES:X(I)
        1           .3000D+00
        2           .3000D+00
        3           .3000D+00
        4           .3000D+00
        5           .3000D+00
        6           .3000D+00
        7           .3000D+00
        8           .0000D+00
        9           .1000D+01
       10           .1000D+01
       11           .1000D+02
       12           .1000D+02
       13           .1000D+02
       14           .1000D+02
       15           .1000D+02
       16           .1000D+02
       17           .1000D+02
       18           .1000D+02
       19           .1000D+02
       20           .1000D+02
       21           .1000D+02
       22           .1000D+02
       23           .1000D+02
       24           .1000D+02
       25           .1000D+02
       26           .1000D+02
       27           .1000D+02
       28           .1000D+02
       29           .1000D+02
       30           .1000D+02
       31           .1000D+02
       32           .1000D+02
       33           .1000D+02
       34           .1000D+02
       35           .1000D+02
       36           .1000D+02
       37           .1000D+02
       38           .1000D+02
       39           .1000D+02
       40           .1000D+02
  OBJECTIVE FUNCTION=  0.1550000D+03AT ITERATION  1580
  STARTING VARIABLES:X(I)
        1           .1000D+01
        2           .1000D+01
        3           .1000D+01
        4           .1000D+01
        5           .0000D+00
        6           .0000D+00
        7           .0000D+00
        8           .0000D+00
        9           .0000D+00
       10           .1000D+01
       11           .1000D+02
       12           .1000D+02
       13           .1000D+02
       14           .1000D+02
       15           .0000D+00
       16           .0000D+00
       17           .0000D+00
       18           .0000D+00
       19           .0000D+00
       20           .1000D+02
       21           .1000D+02
       22           .1000D+02
       23           .1000D+02
       24           .0000D+0
       25           .0000D+0
       26           .0000D+0
       27           .0000D+0
       28           .0000D+0
       29           .1000D+0
       30           .1000D+0
       31           .1000D+0
       32           .1000D+0
       33           .1000D+0
       34           .1000+0
```